

1933

# Course in chemistry derived from problems in industry.

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Sampson, J.S.

Thesis 1933

"A course in chemistry derived from problems in  
industry"

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BOSTON UNIVERSITY SCHOOL OF EDUCATION

THESIS

"A COURSE IN CURRICULUM DEVELOPMENT FROM

PROBLEMS IN EDUCATION"

Submitted by:

JOHN SEYMOUR WATSON

(A. S. Harvard 1933)

In partial fulfillment of requirements for  
degree of Master of Education.

John Seymour Watson, M. Ed., Boston University School of Education  
Thesis, "A Course in Curriculum Development from Problems in Education", 1933.

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DEFINITION OF PROBLEMS

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and instill into the pupils a scientific attitude, and the aim is to develop an appreciation of the role of chemistry in everyday life in the community, home, and industry. The text books on the subject seek to foster the first and make little reference to the latter. For instance, Segorblom (10) in his analysis of these books shows only one stressing the social service of chemistry and all stressing the scientific attitude.

If the text books stress this scientific attitude it might be well to see what the present standing of that attitude is. Reed (46) has the following to say, "Nothing but the blindest optimism can conceal the fact that there is little in the content of a chemistry course to create or even encourage the scientific attitude, with all that the term implies". In making this statement of the fact that "exercises taken from manuals are called experiments by courtesy only". Most of the experiments and topics are not related to the pupils' interests and are "cut and dried" experiments with substances unknown to the average pupil.

Again we find Hall (30) saying, "Most courses tend

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## CHAPTER I

### DEFINITION OF PROBLEM

In treating any high school subject, it is advisable to see what the aims of the course are. In chemistry we find several aims stated in various sources; but there are only two that are found in nearly every case. The first is to foster and instil into the pupils a scientific attitude, and the second is to develop an appreciation of the role of chemistry in everyday life in the community, home, and industry. The text books on the subject seem to favor the first and make little reference to the latter. For instance, Segerblom (48)\* in his analysis of three books shows only one stressing the social service of chemistry and all stressing the scientific attitude.

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are far from scientific". He bases his statement on the facts that often the lectures or class room work do not correspond with the laboratory work, and that the purpose of a course is to make pupils think and not to know just facts, which is not what many courses attain.

Rich (46) as his first misconception of chemical education has, "The belief that the chief actual or desirable outcome of chemical instruction is a 'general training', a 'discipline', a set of 'general abilities' such as those labeled, 'to observe accurately', 'to draw correct or reasonable conclusions', and the like. This doctrine is neither more nor less than a belated survival from pre-scientific psychology". This includes some of the things that people believe should be under the scientific attitude.

Bauden (24) has the following to say; "One course in chemistry will never give much training in the scientific method; but if properly presented, it will give an appreciation of the value of scientific training, which will lead to future courses that will afford such training". This last statement seems to doubt whether a great deal can be done to foster the scientific attitude, and perhaps it would be best to place this as a secondary aim for the present.

The second aim generally stated was the development of an appreciation of the role of chemistry in every day life. According to Fay (28) it was the "Rationalistic and utilitarian

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demands that brought science to the schools". At first chemistry appeared in the curriculum because some knowledge of it was in demand in community life. Today, far more than one hundred years ago when chemistry first entered the schools, it plays a great part in the community life. Almost every industry is chemically controlled, and it is these industries that are the life of a community. There is hardly a thing we use that is not manufactured under chemical control. Therefore, it seems there should still be a great utilitarian demand for it if only to teach the consumer to appreciate the role of chemistry in the products he buys and in the community in which he lives.

Douglass (3) on page 396 says, "First of all, science instruction should give an understanding and appreciation of the applications of scientific principles to the daily environment. The starting point is with problems of immediate concern". And later, on page 397, he says, "Two broad divisions of science instruction are apparent. In his daily work, one meets scientific principles as they are being applied to problems of production. He therefore needs to know scientific principles and their application to industry, at least if he is to do more than routine work. The problem here is education for production; the other, education for intelligent use and consumption of products. In his understanding of street construction, or of a telephone system, or of the problem of water supply, the citizen is in the first instance a consumer; his science problems are very different from those of the skilled mechanic or the engineer employed to

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install or extend a telephone system or to keep it in running order. As head of a household one's problem is not the manufacture of clothing, nor will it be in two thirds or more of the cases the production of foodstuffs; it is how to recognize values and how to buy most economically. The distinction between education for production and education for appreciation or consumption may well play a prominent part in organization of science courses." This and following quotations show that the utilitarian demand has passed from one for production to one of consumption, though the former is still evident.

Twiss (15) pp.5 has the following to say, " It is apparent that modern science and modern social and industrial life are inseparably linked together, and that each in turn causes the other to advance. They must progress hand in hand; otherwise social conditions will become worse instead of better. So since pure science and applied science, the abstract and the concrete, the theoretical and practical, are inseparable in real life outside the school, it is important for the teacher to realize that they should not be divorced in classroom and laboratory."

On page 3 of Hodson (7) he says," So much of modern industry and business, and, indeed, of most sides of modern life is not only based on the discoveries of Science, but depends for efficient performance on a practical knowledge of some or other of its branches, that education without any knowledge of Science is now, whether for boys or girls, well nigh as impractical and absurd as it would be without any knowledge of the 'three R's'."

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Again with regard to the teaching of chemistry on page 173 he says, " There is no adequate reason why chemistry should not be studied from the very beginning in connection with its industrial applications."

Stubbs (54) has the following to say, " Present day methods often aim to turn out chemists rather than intelligent citizens who are appreciative of chemistry." And further on in the selection of material for a course he says, " Select only matter which lends itself to the following general aims; appreciation of commonplace environment, new knowledge applicable to various fields of human endeavor, and training in scientific thinking."

Bell (25) also states " That the public is grossly ignorant of chemistry and the value of chemical knowledge in the solution of public problems needs no argument before a body of this kind. This ignorance exists among educated people, among men of affairs, and among most of those who at the present time comprise our leaders in society and mould public opinion. It is important, therefore, that we take steps to dispel this ignorance. We should see to it that it does not exist among our future leaders, that we plan this course with these future leading citizens definitely in mind. They are more to be considered than the ones who are to specialize in chemistry. Any false notions or any deficiencies in the preparation of the specialist, there will be ample opportunity to correct; but the impression the one-course man carries away is likely to be retained for life."

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Along this same line Bancroft (23) states, " Since chemistry is the fundamental science, the one which we are always encountering in some form and in some place, it is particularly desirable that everybody should have some knowledge of chemistry; and yet the teaching chemists do nothing to make this possible. We have nobody but ourselves to thank for it. The chemists complain, and very properly, that the business men and the bankers are deplorably ignorant of chemistry; but chemists provide no way for the prospective business man to get even the rudimentary knowledge of chemistry as a whole." Relative to this same phase of the subject Gordon (29) states, " Many teachers of chemistry have too long made of their beloved science a sort of sacred cow. To vary the metaphor, we have constructed a Procrustean couch which fits few students, but which every student must be made to fit. We have taught a subject rather than students."

"The average chemistry course of today does not sufficiently prepare the student to understand the everyday world about him. Certainly, it does not give him the knowledge necessary to any intelligent interest in the further development of science. Nearly all of our textbooks include "practical applications", but these are thrown in as after thoughts - at any rate, as entirely secondary to the serious matters of formal chemistry."

Smith HR (49) also has the following to say about chemistry in every day life, " Now, education can be made more attractive and still be dignified. It is not at all necessary

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Osborne (39) also says, " Make the application side of chemistry, its connection to industry, to manufacture, to health, and to every day experience at home and in school, the starting point in as much of our study as possible. Toward this same end utilize the material in the newer books written to popularize chemistry, stimulating in style, and yet based on sound science."

In the government bulletin on the reorganization of science in the secondary schools (31) one finds, " The study of science should give a more intelligent appreciation of the services rendered to society by those individuals who are engaged in vocations of scientific nature and occupations based upon the application of science.....The topics should be chosen on the basis of their fundamental relation to life..... They should relate to local industries, community, and school activities, and the life of the home." And in the report on the correlation of high school and college chemistry with the minimum requirements for a high school course (24) we find stated as the first objective, " To show the service of chemistry to the home, to health, to medicine, to agriculture, to industry etc.; in a word to show the service of chemistry to the country."

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Rich (46) also states as his fourth misconception in chemical education, " That the first year course in chemistry, whether taught in high school or college, is only an introductory course to be followed by other specialized courses." And as to the curriculum of these courses Powers (42) states, " Each of the tests of subject matter points to the conclusion that a large proportion of the content of high school chemistry is of little or no value for many who study it."

Thus as Rich ( 46) says, " High school chemistry courses should be revised with the basic idea that those who take it are not going to study more chemistry, that they are not going to be chemists, and that their specific needs should be met." The figures as set forth by Otto and Inlow (62) indicate that only one person out of two will take a further course in chemistry in higher education, which gives a low figure for those who take

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high school chemistry who will ever take it again. But even if all were to study chemistry further it would not alter the case, for as Caldwell (61) says, "The best education for young people of secondary school age should be best for them whether they go to college or not. Science courses for all the people must help all the people to interpret science for service, not science for power. Service, not power to control, is the needed spirit of modern science instructors."

As Stone (52) says, "The time has come when the rights of the 90% must be more fully realized," but unfortunately we are not doing this. Smith H.R.(49) states, "It is over six years since a committee of the N.E.A. recommended in the reorganization of secondary schools that subjects be taught from the standpoint of their service in life rather than from the academic arrangement according to logical sequence for the subject's sake. Not much heed has yet been paid to this advice by the teachers of any subject. In chemistry some promising titles have appeared on the covers of text books, but a perusal of the content brings out the fact that the title is chiefly advertisement."

Thus the situation is summed up in the following quotation from Jackson (35), "Either the high school course, the college course, or both, must change. I believe we will agree that it is the duty of the high school to do most of the reorganizing, with the help and sympathy of the college."

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"So far, we have been largely destructive. Let us see if we can give some constructive criticism. In the first place, we feel that the high school course should be an inclusive unit within itself and not be dependent upon being capped off at some future period with a college course."

"I propose that the high school chemistry course shall be an intensive appreciation course. Don't pass judgement too quickly on a novel idea. Much will have to be learned in order to appreciate. If all of our high school chemistry students will leave school with some idea of the magnitude of the service of chemistry to our nation, then I feel that we will prosper as we have never done before. When the high school pupils- the masses- realize that it is possible for the chemist to take a waste material like coal tar, and a disagreeable one at that, and produce from it all the hues of the flowers that made the coal, along with their original fragrance, the healing properties of the roots and herbs, the flavors sought the world over by mankind, the sweetness that makes sugar taste like a washed out syrup, the power that will actually do deeds that would make Hercules bow down as a humble servant,- then, my friends, we have pupils who can, to some extent, appreciate the word chemistry. They will never know all about how all these things are done- no never; but they will have a faith and belief that will cause them all their lives to give unto the chemist the things that belong to chemistry."

And further on he says, " When a pupil finds that

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And further on he says, "When a pupil finds that

most industries are chemically controlled; when he finds out that the chemical industries are houses in huge factories and not in test tubes and that they turn out their products by the hundreds of tons; and when he finds that all of this goes into our every day life - then will the pupil appreciate the fact that the chemist is not a pill pounder, but a creator. When this appreciation is built up among the masses that never go to college, then a new day will dawn for the chemist who does finish his education, for the good of each group, the whole nation, and posterity to come ..... He (the pupil) may not know all the details - but he does know that they exist".

Thus one sees there is a demand for a course in chemistry that will give the pupil an appreciation of chemistry in life. The purpose of this paper is to draw a few simple problems from industry, where chemistry plays such an important part, that could be used as a basis to further this appreciation. Then a brief section will be written on methods that appear best to get this appreciation to the pupils and finally a few books that would be excellent to help out the appreciative course.

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Thus one sees there is a demand for a course in chemistry that will give the pupil an appreciation of chemistry in life. The purpose of this paper is to draw a few simple problems from industry, where chemistry plays such an important part, that could be used as a basis to further this appreciation. Then a brief section will be written on methods that appear best to get this appreciation to the pupils and finally a few books that would be excellent to help out the appreciative course.

## LIMITATION OF PROBLEM

When we say that our problems or units are to be derived from industry, we must limit these units. Quotations from Twiss (15) pp 391-2 show how this should be done. He says, "The mistake is often made of straining a point by beginning with some industrial fact or process with which the students are totally unfamiliar and which at the same time is so complicated that it presupposes for its comprehension knowledge of chemical principles that have not yet been studied. Nothing could be worse pedagogically than this. Again the mistake is often made in high school courses in so-called "applied" or "industrial" chemistry of requiring the pupils to memorize complicated details of processes in which no easily perceived application of chemical principles are involved and out of which no clear chemical concepts can be gained. All this with the notion that chemistry is thus being "brought close to daily life". For example, the writer (Twiss) once shared for a recitation period the boredom of a class that was reciting the details of the processes of tanning various kinds of leather. There was no evidence that any one of the class had ever seen a tannery or made a laboratory experiment in tanning, nor did any reference to a chemical principle or any experimental demonstration of whatever sort come out in the recitation or the notes that had been given out to study."

Again on page 393 Twiss says, "Although the industrial applications often involve complicated chemistry and unfamiliar substances, there are nevertheless in every community some applications that can be examined which are simple enough to

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Again on page 393 Twiss says, "Although the industrial applications often involve complicated chemistry and unfamiliar substances, there are nevertheless in every community some applications that can be examined which are simple enough to

be understood. So the teacher should make himself acquainted with these and should connect them with the chemical facts and principles that are applied in them, at the time when these facts and principles are being studied. There are many fairly simple chemical substances and reactions that are fairly common and very important to know about."

In "The Status of Chemistry in Texas High Schools" (51) one finds that the first two in number in the constructive criticisms were, "Relate chemistry to local industries," and "Link chemistry as closely as possible to local conditions." This and the previous quotations give us a basis for limiting our units.

The first limitation should be that the pupils should be familiar with the industry on which the unit is based. It is just as bad to study practical applications of chemistry when not familiar with them as to study nothing but the theories. Thus the industries on which the units are based are local. In and around Boston are many industrial plants on which the every day life of the individual depends. Of course it is realized that in many localities there is not this proximity to the industries. One of these units, water, however, is present in all localities. There are other practical applications that can be substituted. There are many units that can be drawn from household duties such as baking bread, the "turning" of milk, and butter becoming rancid. The units thus chosen should be accessible to the students. All of the industries listed here can be visited by a high school

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class in chemistry, and by means of these visits some knowledge of how they actually run in industry can be obtained. If this knowledge can not be obtained, there is no use in going any further.

The second limitation is that the problems or units will not attempt to give intimate details of the operations but will attempt to show problems that chemistry solved and hence made the industry successful. For instance in water we can show that chlorination is necessary in order to kill harmful bacteria and render it safe for human consumption. Some detail of course will be studied, but only as much as is simple enough for the pupil to grasp easily. For instance in the evaporation of the syrup in the sugar industry it should be stated that it is vacuum evaporation, and how this is done, and why it is done. But the class should not consider details of the construction of the evaporator or the merits of one brand as opposed to another brand. The theories and hypotheses can be connected into the laboratory work, and worked out there, or stated and demonstrated in class rooms; but they are not to be learned until pupils see the necessity for learning. This will be mentioned in detail later.

Another point that should be considered in our units is the history of the industries and their problems. History, for instance, is important in the development of beet sugar to its present status. Another example is the tracing of plagues to water supplies and hence showing the necessity of having pure water. It also gives a clear idea of how quickly an industry can spring up once the problems have been solved as in the case of the

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synthesis of indigo. Another way that the history of the unit should be considered is first having the product and finding a use for it, and thus create the demand. The best example is the production of cotton-seed oil and the cattle fodder obtained from cotton seeds. These were for many years thrown away. The chemist hates to see waste and now those seeds bring in \$150,000,000. a year.

Another point that should be considered is the importance of the industry. The pupil should try to find the uses of the industry himself. The uses of many are obvious; such as water, gas, cotton, and sugar. The amounts used yearly, however, will probably amaze the pupil. He should get some idea of the amounts produced, but should not be forced to learn the exact figures. Then there are other units for which the average pupil could see no use until some of the other units are considered. Caustic soda and sulphuric acid are good examples; but as the pupil sees how these are used and the size of the industries using them, he begins to see where huge amounts of these chemicals are used and hence their importance. The uses should be perfectly clear to the pupil so that he can see the importance of the industry in his everyday life and hence the importance of chemistry to him.

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A last limitation is space. It would require a book to set forth just what should be considered under each unit. Hence in this paper only important points will be mentioned and all details

must be filled in by the individual teacher. At the end of each unit will be mentioned a number of main headings that should be considered, with references. Of course these references are far from being complete, and there are many others that could be substituted. There will also be included a number of theoretical points that are mentioned to help the pupil to understand the unit. How these theoretical points can be best shown to the pupil will be considered in more detail later.

Thus we can arrive at the following form for our units. First, the importance and uses of the products of the industry. Secondly, the amount produced which gives a more or less quantitative measure of its importance to the individual. Third, the history of the development of the industry, what caused it to grow or the solution of what detail made it economically successful. Fourth, the main problems on which the industry hinges. Fifth, a brief description of the industrial processes. Sixth, laboratory work that might be done to clinch the procedure and problems with the pupil. More will be said on the detail of the laboratory work later.

If we follow the above set-up for our units and remember that the industry must be accessible so that the pupils may see them, and they must be presented simply to the pupils, I see no reason why the following units, based on Boston area, will not be successful in giving pupils an appreciation of chemistry in industry and our daily life and some knowledge of the actual processes used in the industries. We will be thankful if we can obtain only the first part.

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CHAPTER III  
METHOD OF ATTACK

The first part of the problem was to obtain the industries on which our units were to be based. Of course the units must be on industries with representatives in this locality and their products must be of universal interest. Therefore, a list of chemical industries in this locality was drawn up for the Boston area. From this was selected a number of industries that played a large part in the everyday life of the citizen of this country. Originally there were only fifteen units but on further consideration five more were added to make a total of twenty industries and consisted of the following:- caustic soda, coke oven gas, cotton, dyeing, fermentation, glass, iron, nitrogen fixation, paper, petroleum, plastics, rayon, rubber, soap, sugar, sulphuric acid, tar, water, water gas, and wool.

Now after we have the industries facts must be gathered about them and three methods were used. The first was by visiting the representative plant of that industry in this vicinity. An interview was arranged with the head chemist. This afforded an opportunity to see the plant and discuss the question with him. As simple as possible a plan of plant operation was drawn up and the chief problems discussed. This afforded a chance to get some information on the history of the industry and uses of the products. Much of this information unfortunately cannot be included, though very interesting, as it is inclined to be too technical and includes much that is only in the experimental stage. The references given were to literature that was also inclined to be highly technical and generally referred to that one industry. Many had tech-



nical journals that discuss the latest improvements and experiments in that particular field. However, the simple plan of plant operation, history, and problems on which the industry rested were of interest.

The second plan was by correspondence with chemists of the writer's acquaintance who were employed in plants of the desired type. Satisfactory replies were obtained and information of the same type was obtained as by the first method except the trip through the plant.

The third method was by means of experiences obtained in working in two of the above industries. These were the rayon and tar industries. Here I had actually come in contact with the operations and literature on that branch of the chemical industries. This afforded an intimate knowledge of problems both solved and in the experimental stage.

Of course this did not furnish complete information on the industries. To fill in and give a simple account of the actual details of operation, Thorpe's "Outlines of Industrial Chemistry" was used as a standard. This is the book that is used as a text in the industrial chemistry course at Harvard University. For the history end of the industries, Miall "History of the British Chemical Industry", and the Encyclopedia Britanica were used to complete information. Then the references used for each unit were checked to see if they fitted the part assigned to them. These references were obtained from Thorpe, Miall, the Encyclopedia,

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Slosson's "Creative Chemistry" and Holmes "General Chemistry".

There are two units about which some doubt can be raised as to their availability to the pupils. The first is that of the extraction of cotton-seed oil. However, this is only one part of the unit and the other part is fairly prominent in this vicinity. The oil part is very valuable as it represents the eternal search of chemists for uses for by-products. It seems, therefore, that if a proper experiment were carried out in the laboratory, it would be valuable to the pupils. The second unit in question is the nitrogen unit. Here again we have a unit in operation, though not as outlined. Legumes grow around here that are always fixing nitrogen from the air. Lightning is always combining nitrogen and oxygen to form compounds that are brought down by rain. The Haber process is only man's way of doing what nature does. If the teacher wishes to confine himself to what can be shown the pupils, let him base his unit on legumes and electrical discharges, but nitrogen is too important to the food crops of the world to be omitted.

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CHAPTER IV  
THE UNITS  
UNIT ON WATER

Probably outside of air, the one compound of most importance to man is water. Man can live without food for a short time but only a very few days without water. It is necessary for his crops that produce the food he eats. It is used in many cases to furnish power to run his engines and motors. It is used in many cases as a cooling device. Many industries that furnish us other products use it as a solvent. Thus water can be termed one of the most important compounds in life. The Greeks recognized this when they made it one of their elements along with air, earth, and fire. Perhaps this can be shown more clearly by showing the consumption of water in one city alone, namely, New York. The figures are taken from page 567 of the World Almanac.

<u>Year</u>	<u>Average Gal. per day per person.</u>	<u>Daily Average Consumption</u>
1925	143.0 Gal.	839,600,000 Gal.
1926	145.7 Gal.	863,300,000 Gal.
1927	145.4 Gal.	868,100,000 Gal.
1928	145.8 Gal.	877,800,000 Gal.
1929	155.1 Gal.	940,400,000 Gal.
1930	143.7 Gal.	995,900,000 Gal.

To maintain a constant supply New York City has two big systems to furnish water. The first is the Croton system that has a storage capacity of 23,141,700,000 Gal., and the second, the Catskill system with a capacity of 181,596,000,000 Gal. which gives a total of 204,737,700,000 Gal. Yet this amount of water would only supply New York for 204+ days.

Then in connection with crops the following figures show the importance of water. These are taken from p.301 of the World Almanac. For every pound of wheat grown, 1044 pounds of

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Year	Average Gal. per day per person.	Daily Average Consumption
1925	143.7 Gal.	825,200,000 Gal.
1926	143.7 Gal.	825,200,000 Gal.
1927	143.4 Gal.	825,100,000 Gal.
1928	143.8 Gal.	827,800,000 Gal.
1929	138.1 Gal.	840,400,000 Gal.
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water are needed, for barley, 831 pounds; for oats, 745 pounds; for potatoes, 263 pounds; and for corn, 227 pounds. Thus we can see the importance of water to the crops that furnish us food.

Water for our crops fortunately does not need chemical attention, but for private use such as for drinking or in industry it must be treated many times. We have to depend on rivers and lakes for our supply, and in many cases it is contaminated with harmful impurities. These can be classed under five headings as in the following table.

<u>Type of Impurity</u>	<u>Example</u>
Dissolved gases	Oxygen, nitrogen, carbon dioxide, hydrogen sulphide
Soluble crystalloids	Salt, Calcium Acid Carbonate, Sodium Sulphate
Colloids	Emulsified oils, gelatine, etc.
Suspended matter	Mud
Bacteria	Typhoid, cholera, etc.

Now some of these substances may be all right for one use and not for another. Thus a certain amount of salts or crystalloids are desirable in drinking water, for if it contains none it is inclined to taste flat as can be shown by tasting distilled water which also lacks dissolved gases. Yet these same salts may make the water unfit for boiler use as they may cause scale on the tubes reducing the efficiency of the boiler and causing the tubes to burn out easily. Bacteria on the other hand is not injurious to water for boiler consumption, but is dangerous to human life.

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It was only in the latter part of the nineteenth century that the importance of water as an epidemic carrier was really recognized and steps taken to prevent it. There are many examples of how epidemics are thus carried. For instance, one winter a patient with typhoid was located in a house whose watershed drained into the town reservoir. When the snow melted, the house refuse was washed into a brook leading into the reservoir. At this time the water was untreated, and an epidemic resulted causing 114 deaths by typhoid in a town of 8000 people. Since the introduction of extensive purification systems the death rate from diseases, the bacteria of which are carried by water, has fallen immensely. Take for instance typhoid fever. In 1880 the death rate was 55 per 100,000 people per year in this country. In 1910 it was 19 and in 1929 it was only 4.2. This shows how pure drinking water can decrease deaths by epidemics.

It is the business of the chemist to remove the impurities in water so that it will be safe to drink. Often he calls nature to help him, and nature does. Rivers are often utilized to remove sewage and waste from cities and factories. If nature did not help the chemist, it would be extremely difficult for the chemist to remove these impurities completely. For instance, Chicago used to empty her sewage into the Chicago river, which emptied into Lake Michigan. Nature did not have much chance to help the chemist and the pollution reached as far away as Milwaukee, and Chicago had a death rate as high as 170 per 100,000 people every year from typhoid. The river was so foul that it

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actually would catch fire. As this situation was so intolerable that something had to be done, they reversed the flow of the Chicago river by deepening it and connecting it with the Illinois, so that the Chicago sewage emptied into the Mississippi. This of course alleviated the trouble on Lake Michigan and the Typhoid death rate in Chicago immediately dropped to 16 per 100,000. The cities on the Mississippi opposed the plan as they said that the sewage would harm them, but strange to say no ill effects were noted. Nature had been called in to help the chemist; but now had she done this?

In the first place mud and other suspended matter has a chance to settle while the water flows along. Then the water has a chance to dissolve oxygen from the air that tends to destroy certain organic compounds and render them harmless. Bacteria of many kinds (anerobic) are also killed by the oxygen. The water is exposed to sunlight that also kills bacteria. Sewage is also used up to a great extent by snails, beetles, mussels, worms, and other organisms. The colloids not already destroyed may be absorbed by materials and carried to the bottom of the river. Harmful gases such as hydrogen sulphide have a chance to escape from the water. Thus we see that running water tends to purify itself.

Even though running water tends to purify itself, it is best to select a source where as few impurities as possible will enter. This is done by selecting a watershed in some sparsely settled region. That is why New York takes its main supply

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from the Catskill mountains. Even here if it has water that comes from bogs or that has percolated through peat, it may contain colored impurities or organic acids formed by decay. However, the purer the source, the less purification needed.

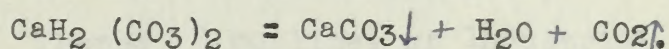
After water has been aerated by spraying it into the air in the form of a fountain in order to dissolve oxygen and allow undesirable gases a chance to escape, the next step is to remove colloids and any suspended matter. This is done by adding some material that tends to adsorb the colloid. Usually  $Al_2(SO_4)_3$  (Aluminum sulphate) is added which forms a flocculent precipitate of  $Al(OH)_3$  in water and adsorbs the colloids and includes the suspended material. This is allowed to settle in sedimentary basins, and is completely removed by filtering thru sand. This has removed all colloids and suspended matter. If objectionable gases have not been removed completely by aeration, or if there are still objectionable crystalloids, they are removed in this same step by adding some material that causes the objectionable part to be precipitated out and leave harmless materials behind. In general the crystalloids are not harmful in drinking water but are in water for boiler use and will be mentioned later. This leaves only bacteria to be dealt with. This is destroyed by chlorination. Chlorine kills bacteria, but is harmful if the excess is not removed later by neutralizing with some substance such as soda. The average amount of chlorine used is about 2.5 pounds per million gallons. This now leaves us with our pure water for personal use.

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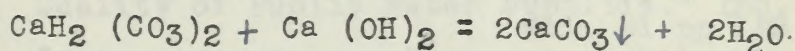
After water has been aerated by spraying it into the air in the form of a fountain in order to dissolve oxygen and allow undesirable gases a chance to escape, the next step is to remove colloids and any suspended matter. This is done by adding some material that tends to agglomerate the colloid. Usually aluminum sulphate ( $Al_2(SO_4)_3$ ) is added which forms a flocculent precipitate of  $Al(OH)_3$  in water and absorbs the colloids and includes the suspended material. This is allowed to settle in sedimentary basins, and is completely removed by filtering through sand. This has removed all colloids and suspended matter. If objectionable gases have not been removed completely by aeration or if there are still objectionable crystalloids, they are removed in this same step by adding some material that causes the objectionable part to be precipitated out and leave harmless materials behind. In general the crystalloids are not harmful in drinking water but are in water for boiler use and will be mentioned later. This leaves only bacteria to be dealt with. This is destroyed by chlorination. Chlorine kills bacteria, but is harmful if the excess is not removed later by neutralizing with some substance such as soda. The average amount of chlorine used is about 2.5 pounds per million gallons. This now leaves us with our pure water for personal use.

Many times our pure drinking water contains salts that form scale on boilers and are thus harmful. Such waters are called hard water. It may be one of two types, temporary or permanent hardness. In waters that are temporarily hard, we find the acid carbonates of calcium and magnesium ( $\text{CaH}_2(\text{CO}_3)_2$  plus  $\text{MgH}_2(\text{CO}_3)_2$ ) This can be removed in three ways as follows:-

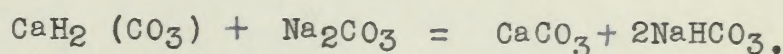
I Boiling the water.



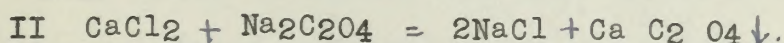
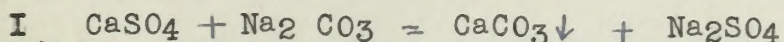
II Treating with milk of lime.



III Treatment with soda-ash.



With permanent hardness it is different. Here we have some material such as Calcium sulphate or chloride. This can be removed but generally only by precipitation, leaving some material behind that is more or less injurious also. Great care must be taken to prevent any excess of the chemical added. Here are two examples of reactions to remove permanent hardness.



In the permutite process, the water is filtered thru an artificial zeolite. Here a reaction similar to that in I, takes place, the Calcium going to the zeolite and the sodium to water. The original zeolite can be regenerated by soaking the spent zeolite in salt solution.

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- I Boiling the water.  

$$\text{CaH}_2(\text{CO}_3)_2 = \text{CaCO}_3 \downarrow + \text{H}_2\text{O} + \text{CO}_2$$
- II Treating with milk of lime.  

$$\text{CaH}_2(\text{CO}_3)_2 + \text{Ca}(\text{OH})_2 = 2\text{CaCO}_3 \downarrow + 2\text{H}_2\text{O}$$
- III Treatment with soda-ash.  

$$\text{CaH}_2(\text{CO}_3)_2 + \text{Na}_2\text{CO}_3 = \text{CaCO}_3 \downarrow + 2\text{NaHCO}_3$$

With permanent hardness it is different. Here we have some material such as Calcium sulphate or chloride. This can be removed but generally only by precipitation leaving some material behind that is more or less injurious also. Great care must be taken to prevent any excess of the chemical added. Here are two examples of reactions to remove permanent hardness.

- I  $\text{CaSO}_4 + \text{Na}_2\text{CO}_3 = \text{CaCO}_3 \downarrow + \text{Na}_2\text{SO}_4$
- II  $\text{CaCl}_2 + \text{Na}_2\text{CO}_3 = 2\text{NaCl} + \text{CaCO}_3 \downarrow$

In the permutite process, the water is filtered thru an artificial zeolite. Here a reaction similar to that in I takes place, the Calcium going to the zeolite and the sodium to water. The original zeolite can be regenerated by soaking the spent zeolite in salt solution.

Thus in a unit on water, the following points should be covered.

I. The importance of water to life.

- Ref. a. Holmes "General Chemistry" or most any other.  
b. World Almanac for figures of consumption in New York or by crops.  
c. The local town water report.

II. Impurities in water and harm from these.

- Ref. a. Holmes "General Chemistry"  
b. Thorpe "Outlines of Industrial Chemistry."  
c. Jordan "Factors contributing to the Quality of Public Water Supplies." Ind. Chem. Vol. 21 pp 153  
d. "Scientific Sewage Disposal at Milwaukee" Ind. Chem. Eng. Vol 20 pp 4.

III.

- Ref. a. Holmes "General Chemistry."  
b. Thorpe "Outlines of Industrial Chemistry."  
c. Hazen "Clean Water and How to Get it."

In the laboratory the following experiments could be performed. With regard to temporary and permanent hardness the methods which are used in industry could be used. For instance, on temporary hardness, a solution of calcium acid carbonate could be made up. Half could be boiled and half treated with milk of lime. Then the resulting soft water could be treated with a soap solution and compared with some temporarily hard water also treated with soap solution.

The purification for drinking would be harder to illustrate in the laboratory as the tendency of running water to

Thus in a salt on water, the following points should

be covered.

I. The importance of water to life.

- a. Holmes "General Chemistry" or most any other.
- b. World Almanac for figures of consumption in New York or by crop.
- c. The local town water report.

II. Impurities in water and harm from these.

- a. Holmes "General Chemistry"
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- c. Jordan "Factors contributing to the quality of Public Water Supplies." Ind. Chem. Vol. 21 pp 103
- d. "Scientific Sewage Disposal at Milwaukee" Ind. Chem. Eng. Vol 20 pp 4.

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In the laboratory the following experiments could be performed. With regard to temporary and permanent hardness the methods which are used in industry could be used. For instance, on temporary hardness, a solution of calcium acid carbonate could be made up. This could be boiled and half treated with milk lime. Then the resulting soft water could be treated with a soap solution and compared with some temporarily hard water also treated with soap solution.

The purification for drinking would be harder to illustrate in the laboratory as the tendency of running water to

purify itself requires time. However, the solubility of a gas such as hydrogen sulphide can be shown by dissolving some in water and then circulating it in a system such that at some time the stream breaks into a jet or fountain. The system can be run some time, and at the end a little copper sulphate added and the amount of CuS precipitated compared with the amount precipitated by some untreated solution of H<sub>2</sub>S. If there were interest enough, the results of aeration on bacteria could be shown in a similar manner by bacteria count before and after. Chlorination can be shown by bacteria count before and after a solution is treated with chlorine. Almost any water taken near where sewage is dumped would contain plenty of bacteria for the experiment. The removal of colloids can be shown by treating some water that contains colloids with Al<sub>2</sub>(SO<sub>4</sub>)<sub>3</sub> and allowing the Al(OH)<sub>3</sub> to settle. There should be some suspended matter present, too, so that its inclusion in the precipitate can be noted. The precipitate could be allowed to settle, and the solution filtered thru sand. These individual experiments show clearly what happens at each step. It might be possible to start with several gallons of water obtained from the same source as the water for the bacteria experiments and run it thru the whole series beginning by aeration and ending with the neutralization of excess chlorine.

Materials needed would be as follows:

- |                       |                           |
|-----------------------|---------------------------|
| 1. Beakers            | 1. Calcium Acid Carbonate |
| 2. Flasks             | 2. Lime water             |
| 3. Bunsen Burners     | 3. Soap solution          |
| 4. Glass Tubing       | 4. Hydrogen Sulphide      |
| 5. Rubber Connections | 5. Chlorine               |

-continued-

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Materials needed would be as follows:

- |                       |                           |
|-----------------------|---------------------------|
| 1. Beakers            | 1. Galsolm Acid Carbonate |
| 2. Flasks             | 2. Lime water             |
| 3. Gansen Burners     | 3. Soap solution          |
| 4. Glass Tying        | 4. Hydrogen Sulphide      |
| 5. Rubber Connections | 5. Chlorine               |

-continued-

-continuation-

6. Aluminum Sulphate
7. Sand and gravel
8. Some colloid
9. Water containing some sewage.

In a unit on water the following theoretical points would help to make the unit clear; colloids, crystallization, filtration, sanitation and germicides, solubility of gases and solids, and specific heat (with regard to scale).

1925	24,701	44,394		
1926	29,372	46,784		
1927	32,352	47,780		
1928	33,350	48,781		
1929	34,344	49,782		
1930	34,742	50,783	70,000	80,000

There is one the United States produces about 25% of the world pig iron and 16.5% of the world steel.

Iron is not found free in nature but is generally combined with oxygen in forms such as hematite (Fe2O3) and magnetite (Fe3O4). Of course, this metal has not been known since the beginning of time and it became known only in the early 18th century, and only after the discovery of the blast furnace. Probably, the earliest known use of iron was as a pigment with some charcoal. Iron is a very important metal. After the discovery of iron, the great demand for iron and steel was about the only metal known to early man. Gold is rare and is extremely soft. Copper is also not so hard as iron and is not so strong. Iron on the other hand is hard. It is more abundant in nature in its ore than

-continuation-

6. Aluminum Sulphate
7. Sand and gravel
8. Some colloid
9. Water containing some sewage.

In a unit on water the following theoretical points would help to make the unit clear; colloid, crystallization, filtration, sanitation and germs, solubility of gases and solids, and specific heat (with regard to scale).

## UNIT ON PIG IRON

Much of our modern civilization depends on one metal, iron. From iron we make steel, and steel can be said almost to support the world. We use it whenever we must support any great weight. All skyscrapers and other tall buildings are made with steel supports and riveted together with steel. Our steel trains run on steel rails. Our ships are made of steel, and so it goes. The following figures show how much is used in this country alone, and are taken from page 361 of the World Almanac.

<u>Year</u>	<u>U. S. Pig Iron</u>	<u>U. S. Steel</u>	<u>World Ave. Pig Iron</u>	<u>World Ave. Steel</u>	
1925	36,701	45,393			Figures are for Thousand metric tons
1926	39,373	48,294			
1927	36,566	44,935			
1928	38,156	51,544			
1929	42,614	56,433			
1930	31,752	40,699	75,000	89,500	

Thus we see the United States produces about 42% of the world pig iron and 45.5% of the world's steel.

Iron does not occur free in nature but is generally combined with oxygen to form red compounds such as hematite ( $\text{Fe}_2\text{O}_3$ ) and magnetite ( $\text{Fe}_3\text{O}_4$ ). Of course this metal was not known to the early barbarians, and when and how it became known are great mysteries. Probably by accident someone heated limonite which was used as a red pigment with some charcoal and metallic iron resulted. After its discovery iron sprang into great demand. Gold and copper are about the only metals known to early man. Gold is rare and is extremely soft. Copper is also soft but not nearly so rare as gold. Iron on the other hand is hard. It is more abundant in nature in its ores than

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	U. S. Pig Iron	U. S. Steel	World Ave. Pig Iron	World Ave. Steel
1933	38,701	45,303		
1932	38,873	46,204		
1931	38,888	44,033		
1930	38,130	41,841		
1929	42,311	50,433		
1928	31,732	40,699	78,000	32,500

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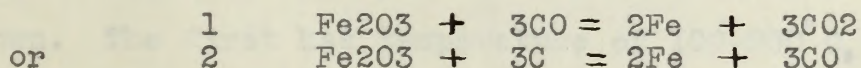
also soft but nearly as rare as gold. Iron on the other

hand is hard. It is more abundant in nature in the ore than

either gold or copper. Hence sprang its great demand, especially for arms where a hard metal is needed, and later for other uses.

It is rather hard to find traces of iron, as it rusts away in time. However, an iron blade was found in one of the pyramids and was probably about 5000 years old. Hardening iron was known to the Greeks and is mentioned by Homer. Iron was probably first found in ashes of fire near some red paint rocks, and on repetition cause and effect were put together. The next step was to make it in a crush forge. Steel was probably an accidental product at first until someone happened to associate carbon with the forming of steel, and thereafter the two were heated together. There was no real improvement in the manufacture of steel until Bessemer in 1856 invented his process for making steel cheaply. The production of steel increased as demands increased and of course the demand for iron. Thus 1806 is the start of the modern iron industry.

The problem in the iron industry is the reduction of the oxides of iron to the metal. This applies the theory of oxidation and reduction. The materials used to reduce are carbon monoxide and carbon and can be represented as follows:

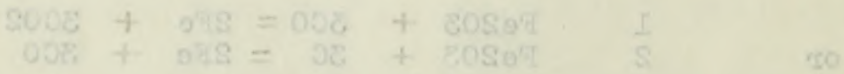


The first equation is of the type that takes place near the top of the blast furnace, while 2 is of the type that takes place lower down. Of course, with the ore there will be some silicates that will be impurities and fuse to form slags.

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The first equation is of the type that takes place near the top of the blast furnace, while 2 is of the type that takes place lower down. Of course, with the ore there will be some impurities that will be impurities and these to form slag.

These being lighter of course float on the top of the fused iron and are tapped off.

In this country there are huge deposits of iron ore in the regions near Lake Superior. In Pennsylvania and Ohio there are also coal beds from which coke can be formed. Thus as coke is needed in the reduction of iron ores, the industry has sprung up in Pennsylvania and other mid-western states around the great Lakes. The water has furnished cheap transportation of the ores to the refining cities.

In this country the reduction is done in huge blast furnaces about 90 feet high and 12 or 14 feet in diameter. Such a furnace can produce 5 to 600 tons of pig iron a day, and this demands 1500-2000 tons of ore, fuel and flux. The ore, coke (source of carbon), and lime stone (flux) are dumped in at the top of the furnace continually. At the bottom a hot blast of air enters and heats the coke and forms carbon monoxide which passes up the furnace. This can be represented by the following equation:  $2C + O_2 = 2CO$ . This partial combustion is what keeps the furnace heated.

The ore, coke, and lime pass thru four zones on its way down. The first has temperature of  $100^{\circ}$ - $200^{\circ}$  C, and here the up coming gas carries off all moisture. In the second zone there is a temperature of  $300^{\circ}$ - $900^{\circ}$  C. The reduction of the ore takes place with carbon monoxide as the reducing agent. This can be represented by the equation of type one as mentioned previously. The third

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In this country the reduction is done in huge blast furnaces about 90 feet high and 12 or 14 feet in diameter. Such a furnace can produce 3 to 500 tons of pig iron a day, and this demands 1500-2000 tons of ore, fuel and flux. The ore, coke (source of carbon), and lime stone (flux) are dumped in at the top of the furnace continually. At the bottom a hot blast of air enters and heats the coke and forms carbon monoxide which passes up the furnace. This can be represented by the following equation:  
$$2C + O_2 = 2CO$$
  
This partial combustion of coal keeps the furnace heated.

The ore, coke, and lime pass down four zones on the way down. The first has a temperature of 100-200°C and here the iron oxide gas carries off all moisture. In the second zone there is a temperature of 500-600°C. The reduction of the ore takes place with carbon monoxide as the reducing agent. This can be represented by the equation of type one as mentioned previously. The third

zone has a temperature of 900-1200 C. Here reduction is completed and is of the second type of equation with carbon being the reducing agent. In the fourth or final zone the temperature is 1200 - 1600 C. Here the iron melts and trickles down to the bottom of the furnace. The iron will dissolve carbon, and any free sulphur or phosphorous. The silica and aluminum present also fuse and go to the bottom, but being lighter float on top of the iron in the form of slag. The slag can be drawn out a notch at the top when necessary. Every 4-6 hours the iron is tapped off and run to pigs; or if it is to be converted to steel immediately, it may be run into ladles and sent molten to the steel plant.

The iron as it goes to the pigs contains 3-4% carbon, 1-3% silicon and some sulphur and phosphorus. This has to be further treated to make steel, but our unit only covers pig iron.

There is another point of note with regard to the making of pig iron. The gas that comes out the top of the furnace still contains some CO that can furnish heat. Part of this is burned to furnish heat to heat the blast of air that enters the furnace. In some plants the rest is run to internal combustion engines and used to produce power. One large American Plant produces 40,000 H.P. from its gas engines.

Then in a unit on pig iron we should consider the following points.

- I Uses of iron and steel and the amounts produced  
Ref. a.) Let the pupils see what uses they can find in their community.

zone has a temperature of 200-2500 C. Here reduction is completed and is of the second type of equation with carbon being the reducing agent. In the fourth or final zone the temperature is 1200-1800 C. Here the iron oxides and silicates down to the bottom of the furnace. The iron will dissolve carbon, and any free sulphur or phosphorus. The silica and alumina present also fuse and go to the bottom, but being lighter float on top of the iron in the form of slag. The slag can be drawn out a notch at the top when necessary. Every 4-6 hours the iron is tapped off and run to pigs or it is to be converted to steel immediately, it may be run into ladles and sent molten to the steel plant.

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There is another point of note with regard to the making of pig iron. The gas that comes out the top of the furnace still contains some CO that can furnish heat. Part of this is burned to furnish heat to heat the blast of air that enters the furnace. In some plants the rest is run to internal combustion engines used to produce power. One large American plant produces 40,000 H.P. from its gas engines.

Then in a unit on pig iron we should consider the following points.

1. Uses of iron and steel and the amount produced
2. How the quality is determined and what they can find in their community.

- b. World Almanac has figures on production
- II. History of production of iron
- Ref. a. Encyclopedia Britanica
  - b. Miall "History of British Chemical Industry"
- III. Supply of production of iron
- Ref. a. Encyclopedia Britanica
  - b. Holmes "General Chemistry"
- IV. Problems of iron industry
- Ref. a. Slosson "Creative Chemistry" Rev.
  - b. Holmes "General Chemistry"
- V. Production of Iron
- Ref. a. Holmes "General Chemistry"
  - b. Thorpe "Outlines of Organic Chemistry"
  - c. Stokes "Non-Technical Talks on Iron & Steel"
  - d. Turner "Metallurgy of Iron".

In the laboratory it will be hard to make a small blast furnace as it must be made of fire clay to withstand the heat sufficient to melt iron. However, it can be done on a small scale with porcelain crucibles. Some limonite can be ground with charcoal and limestone and placed in the crucible and heated with a blast lamp under a hood. This should reduce the ore to metallic iron and show the slag floating on top. This could be poured carefully into a small sand mould to form a small ingot of pig iron.

The materials needed would be as follows:

- |                       |              |
|-----------------------|--------------|
| 1. Porcelain crucible | 1. Limonite  |
| 2. Blast Lamp         | 2. Charcoal  |
| 3. Tongs              | 3. Limestone |
| 4. Sand mould         |              |

b. World market for iron or production

III. History of production of iron

1. a. Geological history

2. b. "History of British Iron Industry"

III. History of production of iron

1. a. Geological history

2. b. "General Chemistry"

IV. Problems of iron industry

1. a. "General Chemistry" Rev.

2. b. "General Chemistry"

V. Production of iron

1. a. "General Chemistry"

2. b. "Outline of Organic Chemistry"

VI. "Non-Technical Talk on Iron & Steel"

1. "General" "History of Iron"

In the laboratory it will be hard to make a small piece

of iron as it must be made of the right size and shape, the heat and

method of rolling iron, however, it can be done in a small scale

with certain exceptions. One method can be carried out with

cool and hydrogen and placed in the crucible and heated with a

blast furnace. This method reduces the iron to cast iron

from and show the iron floating on top. This can be done

carefully into a small tank could be form a small amount of iron

The materials needed would be as follows:

1. Top plate crucible 1. Iron

2. Crucible 2. Carbon

3. Ironstone 3. Hydrogen

4. ...

The only theoretical points needed would be as follows:  
 oxidation-reduction, density, solubility, and heat resisting  
 materials.

It is suggested that some of the work should be done during the course of the project. It is suggested that such an important industry as nitrogen should spring up to help carry the burden and help the project as it was the demand of nitrogen in some fixed form that started the present nitrogen industry. Some figures from page 200 of "Energy Research Quarterly" show the important nitrogen is to be used.

Year 1952	Production	Estimated Demand
Urea	25,000 lbs.	25,000 lbs.
Ammonia	25,000 lbs.	25,000 lbs.
Ammonium sulfate	25,000 lbs.	25,000 lbs.
Ammonium nitrate	25,000 lbs.	25,000 lbs.
Hydrogen	25,000 lbs.	25,000 lbs.
Acetylene	25,000 lbs.	25,000 lbs.
Formaldehyde	25,000 lbs.	25,000 lbs.
Other uses	25,000 lbs.	25,000 lbs.
Total	250,000 lbs.	250,000 lbs.

These figures show that production of nitrogen compounds are required from the 1952 figure. The above mentioned nitrogen will have to be used in some form. Let us see how much nitrogen is produced in some form. The figures are from page 200 of "Energy Research Quarterly" and show the following for 1952.

Production	Estimated Demand
Ammonia	25,000 lbs.
Ammonium sulfate	25,000 lbs.
Ammonium nitrate	25,000 lbs.
Hydrogen	25,000 lbs.
Acetylene	25,000 lbs.
Formaldehyde	25,000 lbs.
Other uses	25,000 lbs.
Total	250,000 lbs.

The only theoretical points noted would be as follows:

oxidation-reduction, energy, solubility, and heat resistance

resistance.

## UNIT ON NITROGEN

The compounds of nitrogen are very important to mankind. It is a part of protein, which is one of the three types of food necessary for life. It is one of the elements necessary in explosives that were in so much demand during the World War. It is unfortunate that such an important industry as nitrogen should spring up to help destroy man rather than help him progress, as it was the demand of nitrogen in some fixed form that started the present nitrogen industry. Some figures taken from page 326 of Holmes "General Chemistry" show how important nitrogen is to crops.

<u>Kind of Crop</u>	<u>Amount</u>	<u>Nitrogen Needed</u>
Corn	25 bu.	39.2 lbs.
Wheat	25 bu.	42.5 lbs.
Oats	25 bu.	24.0 lbs.
Beans	25 bu.	88.0 lbs.
Potatoes	150 bu.	31.5 lbs.
Beets	25,000 lbs.	62.5 lbs.
Cotton	300 lbs.	40.6 lbs.
Tobacco	1,000 lbs.	59.0 lbs.
Sugar Cane	52,000 lbs.	41.4 lbs.
Buck Wheat	20 bu.	77.5 lbs.

These figures show that tremendous amounts of nitrogen compounds are removed from the soil every year, and unless replenished the ground will soon be unfit to grow crops. Let us see how much fixed nitrogen is produced in some year to help replace this. The figures are taken from page 325 of Holmes "General Chemistry" and show World Production for 1929.

<u>Source</u>	<u>Amount</u>
Coke-oven ammonia	414,000 tons
Direct Synthetic Ammonia	980,000 tons
Cyanamide	231,000 tons
Arc Process Nitrate	30,000 tons
Chili salt peter	540,000 tons
Total	<u>2,195,000 tons</u>

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<u>Kind of Crop</u>	<u>Amount</u>	<u>Nitrogen Needed</u>
Corn	25 bu.	39.2 lbs.
Wheat	25 bu.	42.2 lbs.
Oats	25 bu.	24.0 lbs.
Beans	25 bu.	88.0 lbs.
Potatoes	180 bu.	21.2 lbs.
Beets	25,000 lbs.	62.2 lbs.
Cotton	300 lbs.	40.2 lbs.
Tobacco	1,000 lbs.	39.0 lbs.
Sugar Cane	25,000 lbs.	41.2 lbs.
Barley	20 bu.	77.2 lbs.

These figures show that tremendous amounts of nitrogen compounds are removed from the soil every year, and unless replenished the ground will soon be unfit to grow crops. Let us see how much fixed nitrogen is produced in some year to help replace this. The figures are taken from page 385 of Holmes "General Chemistry" and show World Production for 1929.

<u>Source</u>	<u>Amount</u>
Coke-oven ammonia	412,000 tons
Direct synthetic ammonia	280,000 tons
Cyanamide	221,000 tons
Gas process nitrate	50,000 tons
Chili salt peter	840,000 tons
<b>Total</b>	<b>1,783,000 tons</b>

The importance of feeding nitrogen compounds to the soil can be shown by comparing the yield of wheat per acre in countries that use it extensively in fertilizers and those that do not. The figures are taken from page 44 of Slosson's "Creative Chemistry".

<u>Country</u>	<u>Yield per acre before using</u>	<u>Yield per acre after using</u>
Germany	19 bu.	35 bu.
Belgium	30 bu.	35 bu.
France	17 bu.	20 bu.
Great Britain	28 bu.	32 bu.
United States	12 bu.	15 bu.

Thus we can see the tremendous increase in the output of wheat in Germany after the extensive use of fixed nitrogen as a fertilizer.

Nitrogen composes roughly 80% of the air but unfortunately it is of no use to us in this form. We must have the nitrogen in some other form to be of any use to us. Its first use came in gunpowder, or rather this was the first demand for it in fixed form. The Chinese knew gunpowder but only used it for fire-crackers. It was introduced to warfare by either Friar Roger Bacon or Friar Schwartz, and was first used extensively in the battle of Cressy where the English defeated the French. It changed the whole mode of warfare. The first gunpowder required potassium nitrate ( $\text{KNO}_3$ ), which was obtained from manure. In the meantime, other explosives such as guncotton and nitroglycerin were discovered, but these still required nitric acid ( $\text{HNO}_3$ ). In 1878 Nobel invented cordite, and Vieille in 1887 invented smokeless powder. Later came T.N.T. and nitrostarch but these still require nitric acid.

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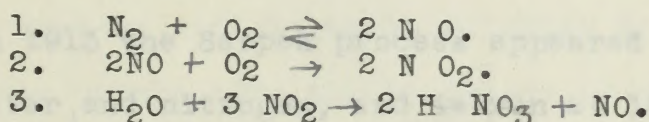
Country	Yield per acre before using	Yield per acre after using
Germany	19 bu.	33 bu.
Belgium	30 bu.	33 bu.
France	14 bu.	30 bu.
Great Britain	28 bu.	33 bu.
United States	18 bu.	18 bu.

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These require great amounts of nitric acid and a cheap source of nitrates. In 1809 Haenke, a German, found the beds of nitrates in Chili. These were not exploited until the last quarter of that century, but from then until 1914 about 53,000,000 tons were removed. At that rate of removal it will not be long before those beds are exhausted.

In the meantime chemists had been looking around for processes by which the tremendous amounts of nitrogen gas in the air might be utilized by making compounds of it. In the early part of the 19th century both Cavendish and Priestly had noted that nitric acid was formed by passing an electric spark through damp air. The percentage of nitrogen converted is very small though, being only five percent at 3327 °C. This reaction can be written in the following steps:-

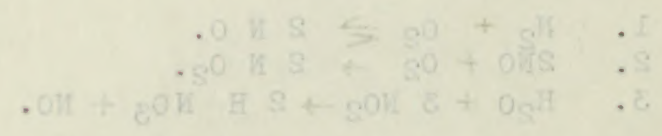


The first commercial attempt at a plant was by Bradley and Lovejoy at Niagara in the year 1902. The plant was not a success, but Birkeland and <sup>Eyde</sup> Eyde, 1903-1905, took over the idea and altered it somewhat, and made a success of it in Norway. This process requires huge amounts of cheap power, and Norway is about the last country where it is being used commercially.

Besides nitric acid and its salts there is another important compound that contains nitrogen. This is ammonia ( $NH_3$ ), and can be converted to nitric acid.  $NH_3$  is a compound of

These require great amounts of nitric acid and a cheap source of nitrates. In 1892 Haaske, a German, found the beds of nitrates in Chile. These were not exploited until the last quarter of that century, but from then until 1914 about 65,000,000 tons were removed. At that rate of removal it will not be long before those beds are exhausted.

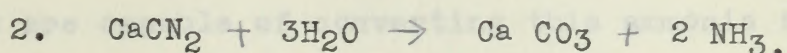
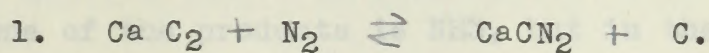
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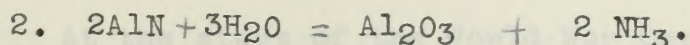
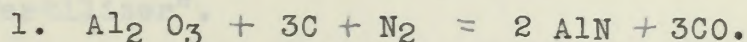
Besides nitric acid and its salts there is another important compound that contains nitrogen. This is ammonia ( $\text{NH}_3$ ), and can be converted to nitric acid.  $\text{NH}_3$  is a compound of

nitrogen and hydrogen. The first process to try and make ammonia was the Frank and Caro process for making cyanamide by passing nitrogen over calcium carbide; this can be sold as fertilizer. If  $\text{NH}_3$  is desired, the cyanamide can be treated with water and ammonia is formed. This industry can be represented by the following equations.



In 1910 the German chemist, Haber, invented a process by the direct combination of hydrogen and nitrogen at high temperature and pressure over a proper catalyst. This can be represented as follows:-  $\text{N}_2 + 3\text{H}_2 \rightleftharpoons 2\text{NH}_3$ . This process also only gives a yield of a few percent.

In 1913 the Serpek process appeared using aluminum oxide, coke, water, and nitrogen, and is run at  $1600^\circ - 2000^\circ$ . This process can be represented as follows:-



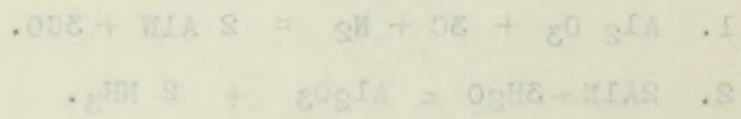
In the meantime, besides needing these processes for the production of explosives, the need for fixed nitrogen as a fertilizer was appearing. In 1840 the German Chemist Liebig pointed out the possibility of maintaining soil fertility by chemical control, after analysis of the soil. Unfortunately it was not as simple as all that and Liebig fell into disrepute. The physicist and the biologist came along to help, and have

nitrogen and hydrogen. The first process to try and make ammonia was the Frank and Caro process for making cyanamide by passing nitrogen over calcium carbide; this can be sold as fertilizer. If NH<sub>3</sub> is desired, the cyanamide can be treated with water and ammonia is formed. This industry can be represented by the following equations.



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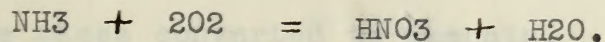


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straightened matters out somewhat so that now there is no doubt but what nitrogen compounds are necessary to maintain soil fertility.

Now if there were no other means besides synthetic nitrogen compounds for replacing the nitrogen in the soil, we would be in a bad way. Nature fortunately also has her own nitrogen industry and helps man out considerably. Leaves and trees fall and decay. One of the products is  $\text{NH}_3$ , but in the ground are certain bacteria that are capable of converting this ammonia to soluble nitrates with an efficiency of 96%. Animal refuse also decays forming  $\text{NH}_3$ , which is treated in the same manner by bacteria. Then there are certain plants, the legumes, that are capable of converting nitrogen in the air to soluble nitrogen compounds. That is why the farmer often plants alfalfa on his lands and turns it in. This fertilizes the soil. Then in the heavens, lightning transforms the nitrogen and oxygen to nitrogen dioxide. This is dissolved and rain brings down minute traces of this that helps to replenish the supply. That is why snow is sometimes called "Poor-man's fertilizer".

At the start of the World War Germany had to depend on Chili for her supply of nitrates; but she was shut off from this by the British fleet. However, she had the Haber process for making ammonia, and this process was soon working to furnish all the  $\text{NH}_3$  needed. Another German, Ostwald, had found that if  $\text{NH}_3$  was passed over a proper catalyst with air it was converted to nitric acid as in the following equation:



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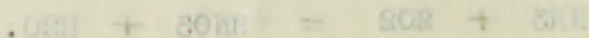
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These two processes allow Germany to be independent of the Chili nitrate supply and mark the start of the nitrogen fixation industry. Other countries found that the Chili nitrate couldn't be brought fast enough for their demands and erected plants of their own. In this country the Muscle Shoal plant was designed to make fixed nitrogen by the Frank and Caro process. Today roughly 56% of the world's supply of nitrogen is fixed synthetically.

The electric arc process is gradually disappearing from industry. Of the others, the Haber process seems to be more extensively used both here and abroad so we shall discuss that process. Nitrogen and hydrogen are needed in their pure forms so that the catalyst will not be poisoned. The nitrogen is prepared from liquid air prepared by the Claude or Linde methods. The nitrogen is obtained pure by distilling the liquid air. Hydrogen is obtained by liquefying water gas. The Hydrogen requiring extreme cold, and pressure will not condense to a liquid while the carbon monoxide and impurities do. This gives us our pure crudes.

The gases are mixed in the proper proportion and passed into the reaction chamber over a catalyst of which there are many. Haber used uranium powder and carbon. The temperature of the chamber is about  $500^{\circ}\text{C}$  and the gases are under a pressure of 150 - 200 atmospheres. The gases, containing now a few percent of ammonia, are passed on to another chamber where the ammonia is dissolved out by some solution such as a solution of ammonium nitrate. The gases are recirculated with enough new crude added to replace the gases converted to ammonia. The  $\text{NH}_3$  is recovered

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to replace the gases converted to ammonia. The NH<sub>3</sub> is recovered

from the  $\text{NH}_4\text{NO}_3$  solution by heating and the  $\text{NH}_4\text{NO}_3$  solution used again.

Thus in a unit on nitrogen the following points should be considered.

I The importance of nitrogen to life and the amounts of nitrogen consumed.

- Ref. a. Holmes " General Chemistry"  
b. Slosson " Creative Chemistry" Revised  
c. "World's Nitrogen Industry Statistics" Ind. Eng. Chem. Vol. 19 pp 196  
d. Material from the Department of Agriculture.

II The nitrogen cycle and how it helps man.

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III History of growth of nitrogen industry.

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c. Slosson " Creative Chemistry"  
d. Thorpe " Outlines of Industrial Chemistry."  
e. "The History and Theory of the Ammonia Synthesis" J. Chem. Ed Vol. 6 pp 2097

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In the laboratory it may be rather hard to show the Haber process. However, H. R. Williams, in J. Chem. Ed. Vol. 8, pp. 462-70 gives a good description of how a model Birkland Eyde plant can be made. Until some experiment showing the Haber process is devised, it would be well to use this experiment to illustrate the fixing of Nitrogen from the air.\*

The following points would help to understand the unit: catalysis, liquefaction of gases, and the effect of temperature and pressure on homogeneous equilibrium.

industry has some small use for sulphuric acid. It has well been said that a community's industries can be judged by the amount of acid it consumes. The following figures show how much acid was consumed in 1928 and by what industries:

<u>Industry</u>	<u>Tons of acid used</u>
Fertilizers	2,360,000
Petroleum Refining	1,570,000
Chemicals	820,000
Dyes and Coal Products	820,000
Steel Pickling	770,000
Metallurgical uses	625,000
Paints and Pigments	315,000
Explosives	195,000
Textiles	85,000
Miscellaneous	320,000
Total	7,925,000

These figures are taken from page 235 of Eyles "General Chemistry", Revised edition.

Sulphuric acid was one of the first products of

\* See discussion of Laboratory Procedure on pages 161-62.

made by Drebbel in 1740 with other plants being created and started in 1756 and 1745. Fixing sulphuric acid was first made

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See discussion of Laboratory Procedure on pages 181-83.

## UNIT ON SULPHURIC ACID

Sulphuric acid can be said to represent one of the two heavy chemicals that have the greatest amount produced. We seldom if ever see them advertised for sale or see them sold. That is because we cannot use sulphuric acid in our everyday life. But it does have many uses in plants that produce things we use. It is used to make other heavy chemicals we need such as muriatic and nitric acid and Glauber's salt. It is used as a drying agent because of the affinity it has for water. It is used to neutralize alkalies as in the rayon and other industries. Nearly every industry has some small use for sulphuric acid. It has well been said that a community's industries can be judged by the amount of acid it consumes. The following figures show how much acid was consumed in 1929 and by what industries:

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Paints and Pigments	215,000
Explosives	195,000
Textiles	85,000
Miscellaneous	320,000
Total	7,925,000

These figures are taken from page 253 of Holmes "General Chemistry", Revised edition.

Sulphuric acid was one of the first products of chemistry to be made commercially. In England it was first made by Drebbel in 1720 with other plants being erected and started in 1736 and 1746. Fuming sulphuric acid was first made

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Explosives	195,000
Textiles	85,000
Miscellaneous	320,000
Total	7,925,000

These figures are taken from page 222 of Holmes' "General Chemistry", Revised edition.

Sulphuric acid was one of the first products of chemistry to be made commercially. In England it was first made by Leibel in 1780 with other plants being erected and started in 1785 and 1786. The first sulphuric acid was first made

at Nordhausen in Saxony in 1755, and has often been called Nordhausen acid. The growth of the manufacture of sulphuric acid if plotted in a curve could be said to represent closely the growth of all chemical industries.

In 1831 it was noted that sulphur dioxide in the presence of oxygen and platinum would be converted to sulphur trioxide, the anhydride of sulphuric acid. Not much was done about it because the platinum catalyst was soon poisoned by the impurities in the  $\text{SO}_2$  and  $\text{O}_2$ . About 1870 Dr. R. Messel found that if the gases were carefully purified, the life of the catalyst was greatly increased. About this time the dye industry was calling for cheap fuming sulphuric acid with an excess of sulphur trioxide. The catalytic process was what was needed and soon began turning out the fuming sulphuric acid for the dye industry.

Sulphuric acid is made by dissolving sulphur trioxide in water as follows:  $\text{SO}_3 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{SO}_4$ . The problem for chemistry is the formation of  $\text{SO}_3$ , as when sulphur is burned we do not get  $\text{SO}_3$ , but the dioxide  $\text{SO}_2$ . They have found two methods for this conversion, the lead chamber, and catalytic process. The first process was the first known and used, but it gives a fairly weak acid. The second process gives a strong acid. Just how the change is made in either case is not known. Some intermediate compound is formed in the lead chamber process, but what it is is only conjecture. Just how platinum acts as a catalyst is not known definitely.

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a catalyst is not known definitely.

In both processes the start is made by burning either sulphur or pyrites ( $\text{FeS}_2$ ) to form  $\text{SO}_2$ . Sulphur was originally used but for a long time Sicily was the chief supply of sulphur, and in 1838 they leased the mines to a French company that raised the price very high. The pyrites from Spain being much cheaper then became widely used. Pyrites is found in this country in Massachusetts and Virginia and was used to make acid. In 1907 Frasch patented a method for obtaining the sulphur that lies underneath swamps in Louisiana and Texas and gives an excellent grade of sulphur and has almost completely replaced pyrites in this country.

In the lead chamber process the  $\text{SO}_2$  is passed to a tower where it comes in contact with the oxide of nitrogen ( $\text{N}_2\text{O}_3$ ) and the intermediate product formed. It then goes to the lead chamber where the intermediate product decomposes to sulphuric acid ( $\text{H}_2\text{SO}_4$ ) and  $\text{N}_2\text{O}_3$ . The chambers have steam in them to help form the acid. The acid collects on the walls of the chambers and trickles down to the bottom. The  $\text{N}_2\text{O}_3$  goes out an exit vent and is dissolved in sulphuric acid and sent back to treat more  $\text{SO}_2$ .

In the catalytic process, the  $\text{SO}_2$  is first purified to get rid of substances that would poison the catalyst platinum. The  $\text{SO}_2$  is then passed over platinum with air and the  $\text{SO}_3$  formed. This is dissolved in concentrated  $\text{H}_2\text{SO}_4$  and then diluted with water to give  $\text{H}_2\text{SO}_4$ .

In brief what should be covered in a unit on the

In both processes the start is made by burning either sulphur or pyrites (FeS<sub>2</sub>) to form SO<sub>2</sub>. Sulphur was originally used but for a long time Sicily was the chief supply of sulphur, and in 1838 they leased the mines to a French company that raised the price very high. The pyrites from Spain being much cheaper then became widely used. Pyrites is found in this country in Massachusetts and Virginia and was used to make acid. In 1867 Frasch patented a method for obtaining the sulphur that lies underneath swamps in Louisiana and Texas and gives an excellent grade of sulphur and has almost completely replaced pyrites in this country.

In the lead chamber process the SO<sub>2</sub> is passed to a tower where it comes in contact with the oxide of nitrogen (N<sub>2</sub>O<sub>5</sub>) and the intermediate product formed. It then goes to the lead chamber where the intermediate product decomposes to sulphuric acid (H<sub>2</sub>SO<sub>4</sub>) and SO<sub>2</sub>. The chambers have steam in them to help form the acid. The acid collects on the walls of the chambers and trickles down to the bottom. The SO<sub>2</sub> goes out an exit vent and is dissolved in sulphuric acid and sent back to treat more SO<sub>2</sub>.

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manufacture of  $H_2SO_4$  is as follows:

- I. The uses and consumption of  $H_2SO_4$ .  
Ref. a) Holmes "General Chemistry Revised"  
b) Units already studied. (To show uses)
- II. History of development.  
a) Miall "History of the British Chemical Industry"  
b) Thorpe "Outlines of Industrial Chemistry"
- III. Sources of Sulphur.  
a) Thorpe "Outlines of Industrial Chemistry"  
b) Mineral Resources of United States for 1907  
(Pt. II) pp. 674.
- IV. Brief description of processes.  
a) Thorpe "Outlines of Industrial Chemistry"  
b) Lunge "Suplhuric Acid & Alkali" Vol. I.

In the laboratory it would perhaps be well to illustrate only one process, the catalytic process. The sulphur could be burned on a grate of some sort or on a screen with a metal box placed over it. Air can be blown in the bottom to give oxygen for combustion. The  $SO_2$  and excess air can go out a vent in the top of a box and be cooled by circulating thru a circular glass tube. It should then be washed by water and is now ready for the final reaction. The gas should be slowly passed thru a pyrex tube and heated strongly by Bunsen burners so that the temperature of the gas is about  $400^\circ - 500^\circ C$ , and then passed into another iron box that contains our catalyst. (At this temperature almost any surface can be used). The catalyst causes our  $SO_2$  to become  $SO_3$ . This can be absorbed in  $H_2SO_4$  and concentrate our acid. This experiment can be repeated with pyrites instead of sulphur.

With the sulphuric acid made, several experiments

Manufacture of H<sub>2</sub>SO<sub>4</sub> is as follows:

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In the laboratory it would perhaps be well to

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could be burned on a grate or on a screen with a

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concentrate our acid. This experiment can be repeated with pyrites

instead of sulphur.

With the sulphuric acid made, several experiments

UNIT ON CAUSTIC SODA

should be run to show the action of sulphuric acid on metals; aluminum, copper, iron, lead, tin, and zinc can be used. This should show why any solution containing sulphuric acid is generally placed in lead containers.

Material needed would be:

- a) 2- iron or lead boxes with two vents in each.
- b) 1 - Pyrex Tube
- c) 1 - 1-liter flask for "scrubbing"
- d) Rubber tubing and stoppers
- e) Glass tubing
- f) 2 - 500 cc. beakers
- a) one pound of sulphur
- b) one pound of pyrites
- c) Some catalytic surface
- d) Metals such as Al, Cu, Fe, Pb, Sn, and Zn.

Industry

Total of Caustic Soda

The following theoretical points should be mentioned to help understand the unit thoroughly and are as follows: acids and their anhydrides, acids v.s. bases, acid corrosion, catalysis, oxidation reduction, solubility of gases, and the effect of temperature on reaction equilibrium.

Vegetable Oils	11,000
Pulp and Paper	87,000
Miscellaneous	25,000
Total Used	662,500

The production of Caustic Soda was for a long time connected very closely with the production of soda, (Na2 CO3) as it was from soda that the caustic was produced. For that reason the history of caustic soda was the same as that of soda until 1886-88, when a rival process appeared. Up until 1890 there was no process to compete with the crude soda. In 1878 the Academie of France offered a prize for the best method of making soda as she was cut off from the supplies of crude soda by wars. In 1890 the prize was awarded to Nicolas Leblanc for a method using

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|--------------------------------------|---|
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| b) 1 - Pyrex tube                    | b) one pound of pyrites                       |
| c) 1 - 1-liter flask for "scrubbing" | c) Some catalytic surface                     |
| d) Rubber tubing and stoppers        | d) Metals such as Al, Cu, Fe, Pb, Sn, and Zn. |
| e) Glass tubing                      |   |
| f) 2 - 500 cc. beakers               |   |

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## UNIT ON CAUSTIC SODA

Caustic Soda or sodium hydroxide is another important chemical that is widely used, but of which the ordinary individual sees little. Like sulphuric acid it is used in many industries to help make products with which we are familiar. Thus it is used to make phenol and the cresols, soap, in dyeing and in the textile industries. Its widespread usage can be seen in the following figures for the distributed usage of sodium hydroxide (NaOH) in 1929. The figures are taken from Holmes "General Chemistry", Revised, page 198.

<u>Industry</u>	<u>Tons of Caustic Used</u>
Soap	103,000
Chemicals	90,000
Petroleum Refining	116,000
Rayon	105,000
Lye	25,000
Exports	62,000
Textiles	40,500
Rubber Reclaiming	40,000
Vegetable Oils	11,000
Pulp and Paper	37,000
Miscellaneous	33,000
Total Used	662,500

The production of Caustic Soda was for a long time connected very closely with the production of soda, ( $\text{Na}_2\text{CO}_3$ ) as it was from soda that the caustic was produced. For that reason the history of caustic soda was the same as that of soda until 1886-92, when a rival process appeared. Up until 1790 there was no process to compete with the crude soda. In 1775 the Academie of France offered a prize for the best method of making soda as she was cut off from the supplies of crude soda by wars. In 1790 the prize was awarded to Nicolas Leblanc for a method using

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Textiles	40,500
Rubber Retaining	40,000
Vegetable Oils	11,000
Pulp and Paper	37,000
Miscellaneous	23,000
Total Used	662,000

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salt, sulphuric acid and lime stone. A plant was erected at Saint Dennis in 1791 using this process and from that time on it gradually expanded. Thus we see that another industry received benefit by one country's supply of a material being shut off by a war.

The Leblanc process made certain improvements to make it more efficient but had no rival until the ammonia-soda or Solvay process came along. This was experimented with as early as 1810 by Fresnel in France, but he did not try it commercially. In 1836 Thorn tried it commercially at Camlachie in Scotland but failed. In 1838, 1840, 1842, 1854 and 1858 others tried it but all failed. This shows how difficult it is sometimes to make things pay on a large scale that seem perfectly easy to perform in the test-tube.

In 1865 in Belgium, Ernest Solvay started a plant with some variations on the old plans. It worked and spread very rapidly. In 1873 it went to England, to the United States and Russia in 1881, to Germany and Austria in 1885. This process rapidly replaced the Leblanc process and in 1902 out of 1,800,000 tons of soda made, 1,650,000 tons was made by the Solvay process. But still, despite this change caustic soda was made in the same way.

In 1886, H. Y. Castner, An American, went to London with an idea of making metallic sodium by the electrolysis of salt. Kellner, an Austrian, was working on the same idea at

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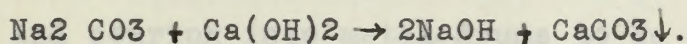
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the same time and in 1895 these two formed a company for the manufacture of caustic soda, as they found that it would pay to allow the sodium formed to react with water and form caustic soda as follows:  $2\text{Na} + 2\text{H}_2\text{O} \rightarrow 2\text{NaOH} + \text{H}_2\uparrow$ . The products of this type of reaction are caustic soda, chlorine, and hydrogen. This has become a serious competitor of the old method and would be more so if new uses could be discovered for chlorine and hydrogen, as it is only economical to make as much caustic as they can dispose of the chlorine generated in the electrolysis of the brine.

In the old method the problem for the chemist is the changing of soda ( $\text{Na}_2\text{CO}_3$ ) to caustic soda ( $\text{NaOH}$ ). This is done by treating with slaked lime ( $\text{Ca(OH)}_2$ ). The lime reacts with the soda to form caustic soda and calcium carbonate as follows:

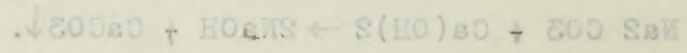


The calcium carbonate is insoluble and settles at the bottom of the containers in which the reaction is carried out. The liquid caustic solution evaporated until impurities such as sodium carbonate or chloride crystallize. Then the liquor is again drawn off and the water boiled off and the caustic fused. The caustic is then run into drums where it solidifies and is sold in this form.

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the same time and in 1895 these two formed a company for the manufacture of caustic soda, as they found that it would pay to allow the sodium formed to react with water and form caustic soda as follows:  $2Na + 2H_2O \rightarrow 2NaOH + H_2 \uparrow$ . The products of this type of reaction are caustic soda, chlorine, and hydrogen. This has become a serious competitor of the old method and would be more so if new uses could be discovered for chlorine and hydrogen, as it is only economical to make as much caustic as they can dispose of the chlorine generated in the electrolysis of the brine.

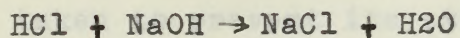
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In the electrolytic method the problem is the cheap production of metallic sodium by electrolysis and the subsequent reaction of the sodium with water. The second problem

is to keep the sodium from reacting in the electrolytic chamber, as chlorine, the other product, is soluble in water to form hydrochloric acid which reacts with the caustic to destroy it as follows:



This gives us our original materials. They may try to prevent it by keeping the materials apart by means of diaphragms. Or lastly they may fuse NaCl (salt) so as there will be no water present.

The method used by Castner and Kellner was to have a mercury cathode in the electrolytic chamber on which the sodium forms. The sodium forms an amalgam with the mercury that is not attacked by brine solution but on removal and placing in water is attacked to form caustic and the mercury is recovered and used again. The solid caustic is again formed by evaporation, fusing, and pouring into metal drums to be sold.

Thus in a unit on caustic soda one should mention

- I. Amount of Caustic produced and its widespread use.  
Ref. a.) Holmes "General Chemistry"  
b.) Thorpe "Outlines of Industrial Chemistry"
- II. History of the development of the Industry.  
Ref. a.) Miall "History of the British Chemical Industry"  
b.) Solvay "Brunner, Mond & Co. 50th Anniversary"  
J.S.C.I. 1919 p.113.  
c.) Castner J.S.C.I. 1899 pp 901, 986.
- III. Brief description of production by both processes.  
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In the laboratory both methods could be illustrated.

In the old method a solution of soda can be made up and milk of lime added. The precipitate can be filtered off or the liquid decanted. It can be evaporated to dryness and then fused. The fused mass could be poured into some mould to harden. Care should be taken to prevent its striking or touching the pupil as it is very corrosive.

In the electrolytic method we could use a glass pneumatic trough to contain our brine solution. The mercury can be placed in a small beaker and our wire run into it. The current can then be passed thru the cell. This should be done under a hood so as to minimize the danger from any escaping chlorine. It would be well to have two sets of mercury electrodes so while one is in the electrolytic cell the other can be in water where the sodium reacts with it.

Materials needed would be as follows:

- |                          |                  |
|--------------------------|------------------|
| 1. 3 - 1 Liter beakers.  | 1. Soda.         |
| 2. 2 - 100 c.c. beakers. | 2. Milk of lime. |
| 3. 1 - Iron Crucible     | 3. Mercury.      |
| 4. Bunsen burners.       | 4. Water.        |
| 5. Filtration funnel.    | 5. Salt.         |
| 6. Pneumatic trough.     | 6. Filter paper. |
|                          | 7. Batteries.    |

To understand completely a unit on caustic soda the following theoretical points need to be touched: acids v.s. bases, bases from reaction of metals on water, crystallization, electrolysis and ions and solubility of solids.

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To understand completely a unit on caustic soda the following theoretical points need to be touched: acids v.s. bases, bases from reaction of metals on water, crystallization, electrolysis and ions, and solubility of solids.

There are several products obtained from the distillation of petroleum and consist of gasoline, kerosene, gas and fuel oil, lubricating oil, wax-coke asphalt, and other miscellaneous oils. These have very recently sprung into use. Gasoline has come into great demand especially since the automobile has come into common use. Kerosene used to be in great demand as a fuel for lights. Fuel oil is being used more every day for heating houses. The oils are used to lubricate machinery. The demand for these products has reached great proportions and can be shown best by the following figures taken from page 358 of the World Almanac.

Crudes run to still

Year	Domestic Crude	Foreign	Total
1925	698,582,000	4,325,000	702,907,000
1926	734,301,000	4,325,000	738,626,000
1927	778,729,000	5,000,000	783,729,000
1928	835,711,000	7,000,000	842,711,000
1929	912,191,000	7,000,000	919,191,000
1930	866,615,000	6,000,000	872,615,000

material handled every year.

In this country petroleum is found in Texas, Oklahoma, California, and in the east in Pennsylvania. As the petroleum comes from the ground, it is a black oily liquid that looks very different from the finished product. Just how these deposits of petroleum occurred is not exactly known. It seems probable that it is the result of the decay of animal and vegetable matter under layers of sediment. An earlier idea was that it was the

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Materials needed would be as follows:

- |                  |                          |
|------------------|--------------------------|
| 1. Soda.         | 1. 3 - 1 liter beakers.  |
| 2. Milk of lime. | 2. 2 - 100 c.c. beakers. |
| 3. Mercury.      | 3. 1 - Iron Crucible     |
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Year	Domestic Crude	Foreign
1925	698,582,000	4
1926	734,301,000	
1930	899,812,000	
1938	915,181,000	

These figures represent barrels of material, and as every barrel holds 42 gallons, this represents a huge volume of material handled every year.

In this country petroleum is found in Texas, Oklahoma, California, and in the east in Pennsylvania. As the petroleum comes from the ground, it is a black oily liquid that looks very different from the finished product. Just how these deposits of petroleum occurred is not exactly known. It seems probable that it is the result of the decay of animal and vegetable matter under layers of sediment. An earlier idea was that it was the



## Crudes run to still

## Refined products

Year	Crudes run to still		Refined products			
	Domestic Crude	Foreign Crude	Gasoline	Kerosene	Gas & Fuel Oils	Lubricants
1925	698,582,000	41,338,000	259,601,000	59,689,000	364,991,000	31,055,000
1926	734,301,000	44,963,000	299,734,000	61,768,000	365,195,000	32,293,000
1927	778,729,000	50,106,000	330,435,000	56,113,000	393,066,000	31,721,000
1928	835,711,000	77,584,000	376,945,000	59,353,000	427,237,000	34,658,000
1929	912,191,000	75,517,000	435,078,000	55,940,000	448,949,000	34,359,000
1930	866,615,000	60,832,000	436,217,000	49,208,000	373,162,000	34,201,000

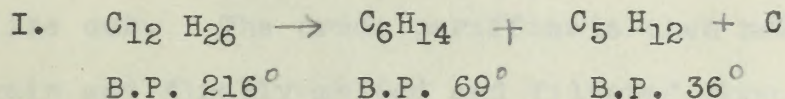
There are several products obtained from the distillation of petroleum and besides of gasoline, kerosene, and fuel oil, lubricating oil, wax, asphalt, and other specialties are obtained. These have very variously varying uses. Gasoline is used for motor cars, and especially for aviation purposes. It is also used for lighting, and for heating. The oil used for lighting is being used more and more for the motor. The oil used for heating is being used for these purposes. The oil used for heating is being used for these purposes. The oil used for heating is being used for these purposes.

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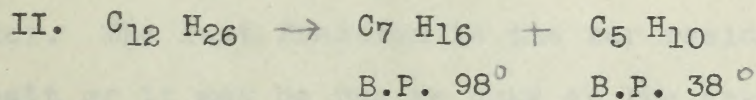
result of the action of water on metallic carbides.

Petroleum was known as early as 450 B.C., as Herodotus writes that it was known to the Persians. But as no one had any use for the crude oil, nothing was done about it. Not until Colonel Drake in 1859 drilled a well at Oil City, Pa. was there any use for it. Its earliest use was for kerosene for heating and lighting purposes. In 1906, 33,000,000 barrels of kerosene were produced, and practically no gasoline. Now the gasoline produced is about 13 times that amount.

Until 1913 the petroleum industry confined itself to straight distillation. The middle fraction had practically no use and was a drag on the industry. In this year, however, Burton found that if these oils were heated and subjected to pressure, the hydrocarbons would "crack" to yield more gasoline. This can be represented as follows:



or

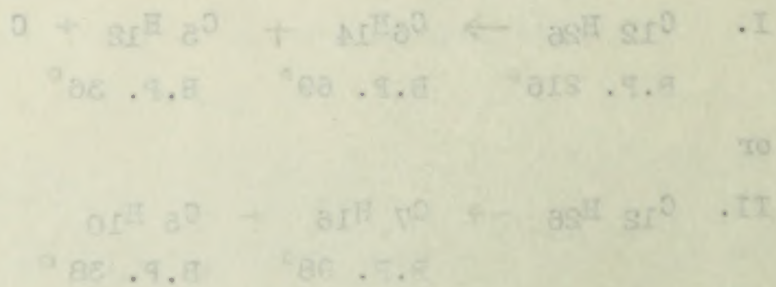


This process enabled a product with few uses to be turned into a valuable product. In 1928 only about one half of the gasoline was made by straight distillation, one third by cracking, and one tenth was "casing-head" gasoline. Cracking is still increasing and is the thing that keeps the price of

result of the action of water on metallic carbides.

Petroleum was known as early as 450 B.C., as Herodotus writes that it was known to the Persians. But as no one had any use for the crude oil, nothing was done about it. Not until Colonel Drake in 1859 drilled a well at Oil City, Pa. was there any use for it. Its earliest use was for kerosene for heating and lighting purposes. In 1906, 35,000,000 barrels of kerosene were produced, and practically no gasoline. Now the gasoline produced is about 15 times that amount.

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gasoline low and prevents a lack of the product.

There are two problems for the chemist. The first is the turning of the black petroleum into clear, clean products. The second is the transformation of the products with little or no use to products that have use; this is our cracking process.

In the first problem the crude oil is simply distilled and separated in various fractions. The first fraction is our gasoline and has a boiling point of about  $115^{\circ}$  F. This is a mixture of various compounds that can be separated further by further fractional distillation. Kerosene is the second fraction and has a boiling point of  $210^{\circ}$  -  $300^{\circ}$ . The third fraction is the fuel oils and has a boiling point of  $225^{\circ}$  -  $375^{\circ}$ , and is also used in cracking. The lubricating oils are the fourth fraction and boil about  $350^{\circ}$ . It is from this fraction that vaseline and paraffine are obtained, by treating with acid and chilling until they crystallize out. The crude paraffine is then melted and crystallized again and finally melted and filtered thru bone char to give the white commercial paraffine. The preparation of vaseline is similar. The last fraction is the tar residue that is used for asphalt, or it may be run to coke as the coke has use in making electrical supplies.

In the second problem the middle fraction is heated to  $375^{\circ}$  C and subjected to a pressure of about 100 pounds. The "cracking" takes place to form gasoline, coke, and some gas. The gasoline is condensed in condensers and added to the other.

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and separated in various fractions. The first fraction is our gasoline and has a boiling point of about 115° F. This is a mixture of various compounds that can be separated further by further fractional distillation. Kerosene is the second fraction and has

a boiling point of 210 - 300°. The third fraction is the fuel oils and has a boiling point of 325 - 375°, and is also used in cracking. The lubricating oils are the fourth fraction and boil about 380°. It is from this fraction that vaseline and paraffine

are obtained, by treating with acid and chilling until they crystallize out. The crude paraffine is then melted and crystallized again and finally melted and filtered thru bone char to

give the white commercial paraffine. The preparation of vaseline is similar. The last fraction is the tar residue that is used

for asphalt, or it may be run to coke as the coke has use in making electrical supplies.

In the second problem the middle fraction is heated to 375° C and subjected to a pressure of about 100 pounds. The "cracking" takes place to form gasoline, coke, and some gas. The gasoline is condensed in condensers and added to the other.

The gas ( blau gas ) is rich in methane and hydrogen that furnish a great deal of heat on burning. This gas can be used as a fuel, or it can be sold to gas companies that use it to enrich water gas and make the water gas meet the specifications for heat set forth. This mixture can then be sold as illuminating gas.

Thus in a unit on Petroleum we should mention the following points.

#### I. Production and Uses of Petroleum

- Ref. a. Holmes " General Chemistry"  
b. World Almanac  
c. Gruse " Petroleum and its Products."

#### II. Origin of Petroleum

- Ref. a. Brannt " Petroleum; Its History, Origin, Etc."  
b. Phillips " The Origin of Petroleum & Natural Gas."- Am. Chem. J. Vol. 16 pp 406.  
c. Sadtler. " Origin & Chemical Composition of Petroleum."

#### III. History of Petroleum Industry

- Ref. a. Thorpe " Outlines of Industrial Chemistry"  
b. Brannt " Petroleum; Its History, Origin etc."  
c. Leet " Petroleum Distillation."

#### IV. Brief description of processes in industry.

- Ref. a. Boyd, " Gasoline."  
b. Leet, " Petroleum Distillation."  
c. Thorpe, " Outlines of Industrial Chemistry."

In the laboratory it would be a simple matter to show the distillation of petroleum. Some crude oil could be obtained from a refinery or from one of the companies producing crude oil. This could be set up to a liter distillation flask with a thermometer attached and the first three fractions collected by boiling

The gas (blast gas) is rich in methane and hydrogen that furnish a great deal of heat on burning. This gas can be used as a fuel, or it can be sold to gas companies that use it to enrich water gas and make the water gas meet the specifications for blast gas. This mixture can then be sold as illuminating gas.

Thus in a unit on petroleum we should mention the

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### I. Production and Uses of Petroleum

- Ref. a. Holmes "General Chemistry"
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- c. Grasse "Petroleum and its Products."

### II. Origin of Petroleum

- Ref. a. Brandt "Petroleum; Its History, Origin, Etc."
- b. Phillips "The Origin of Petroleum & Natural Gas." - Am. Chem. J. Vol. 16 pp 408.
- c. Sadler "Origin & Chemical Composition of Petroleum."

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### IV. Brief description of processes in industry.

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In the laboratory it would be a simple matter to show the distillation of petroleum. Some crude oil could be obtained from a refinery or from one of the companies producing crude oil. This could be set up to a liter distillation flask with a thermometer attached and the first three fractions collected by boiling

and condensing in a straight condenser. For the lubrication oils it would be well to change to vacuum distillation by sealing the system and attaching the flask catching the distillate to an ejector. This will prevent carbonization in our distilling flask. The distillation can be carried to asphalt or coke. The fractions should be compared for boiling point and flash point as gasoline depends on its low flash point.

To illustrate cracking would be harder. A special chamber would have to be made, preferably by the pupils, so that it could withstand the high temperature and pressure. It might be well to make it in the form of a bomb with a screw top. Enough liquid could be placed in it so that when vaporized the pressure would be 100 pounds and could be calculated from the combined gas law. The top could be screwed on and the bomb placed in a furnace that has been heated to about  $400^{\circ}\text{C}$ . and left for some time. Then the bomb could be cooled and opened. The products of the bomb could then be compared with some of the original middle fraction and any cracking noted. The bomb should be large enough so that enough product would be obtained for distillation, as this would best show any cracking. \*

Material needed for this experiment would be as follows:

- |  |                                    |
|--|------------------------------------|
| 1. 2-1 liter distillation flasks.      | 1. 1 or 2 gal.                     |
| 2. 2 condensers                        | of crude oil                       |
| 3. 1 - ejector                         | 2. $\text{H}_2\text{SO}_4$ & Na OH |
| 4. Thermometers                        | 3. Ice and salt solution           |
| 5. A "bomb" for cracking               | 4. Bone-char                       |
| 6. Several 150 cc. distillation flasks |                                    |
| 7. Rubber tubing                       |                                    |
| 8. 1 - Separatory funnel (500 cc.)     |                                    |

\*Experiment very dangerous and difficult. See discussion of laboratory procedure on pages 161-162.

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1. 2-1 liter distillation flasks. 1. 1 or 2 Gal.
2. 2 condensers
3. 1 - ejector
4. Thermometers
5. A "bomb" for cracking
6. Several 100 cc. distillation flasks
7. Rubber tubing
8. 1 - Laboratory funnel (500 cc.)

\*Experiment very dangerous and difficult. See discussion of laboratory procedure on pages 161-162.

If desired, perhaps paraffine could be separated from the lubricating oils, washing the paraffine oil in a separatory funnel with acid and alkali and chilling for some time until the paraffine crystallizes out. This could be chilled with ice and salt solution (or better  $\text{CaCl}_2$ ). The paraffine could be removed, recrystallized, and finally filtered thru bone-char as done with sugar.

The following theoretical points would help to understand the unit thoroughly: the theory of distillation, the effect of pressure and temperature (for cracking), flash point, and solubility and temperature.

1932 12,000,000,000 cu. ft.

United States production of illuminating gas for the year 1932 was 12,000,000,000 cubic feet. This figure was also obtained from the Boston Consolidated Gas Company.

An interesting pamphlet can be obtained from the company showing the various uses of gas to be used for heat, or for industrial purposes.

It has been known for a long time that coal sometimes gives off a gas that could be used as an illuminating gas. As early as 1837, Thomas Shirley of England had a patent for a process for making this gas. It was also known for some time that coal could be distilled to yield tar and gas, and Martin Kapp had a patent as early as 1838. For a long time, however, coal

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The following theoretical points would help to  
understand the unit theory: the theory of distillation, the  
effect of pressure and temperature (for cracking), flash point,  
and solubility and temperature.

In our country we use a great deal of gas for heating and lighting purposes. Lately the production of gas for lighting purposes has declined; but its demand for heating purposes has increased. Gas gives a clear non-smoking sootless flame. It can be kindled instantly and is then ready for use. When one is finished, the gas may be turned off. With our coal or wood fires we have no such quick control, nor is it so clean a source of heat, having ashes and smoke. In this country there are three sources of gas for fuel, natural gas, coal gas, or coke oven gas, and water gas; but in this part of the country only coal gas, or coke oven gas, and water gas are made. The following figure shows how much coke oven gas is used as a fuel. The figure is for the year 1932 and was obtained from the Boston Consolidated Gas Company.

1932                    12,000,800,000 cu. ft.

United States production of illuminating gas for the year 1932 was 527,000,000,000 cubic feet. This figure was also obtained from the Boston Consolidated Gas Company.

An interesting pamphlet can be obtained from that Company, showing the merits of gas to be used to cook, heat, or for industrial purposes.

It has been known for a long time that coal sometimes gives off a gas that could be used as an illuminating gas. As early as 1667, Thomas Shirley of England had a patent for a process for making this gas. It was also known for some time that coal could be distilled to yield tar and gas, and Martin Ecle had a patent as early as 1694. For a long time, however, coal

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1932 12,000,800 cu. ft.

United States production of illuminating gas for the year 1932 was 327,000,000 cubic feet. This figure was also obtained from the Boston Consolidated Gas Company.

An interesting pamphlet can be obtained from that Company showing the merits of gas to be used to cook, heat, or for industrial purposes.

It has been known for a long time that coal sometimes gives off a gas that could be used as an illuminating gas. As early as 1667, Thomas Shirley of England had a patent for a process for making this gas. It was also known for some time that coal could be distilled to yield tar and gas, and Martin Bole had a patent as early as 1824. For a long time, however, coal

was only distilled for the coke that was left behind. In 1787 the Earl of Dundonald used the gas from the distillation of coke to light an Abbey, though in 1785 Professor Winchellers had lighted his lecture hall by this gas.

The first commercial production of coal gas for lighting purposes was done about the same time by Murdoch in England, and Lebon in France. Murdoch lighted his house in Redruth in 1792. In 1797 he lighted a house in Ayrshire, and in 1802 the factory of Boulton and Watt in Soho. In 1801 Lebon lighted a house in Paris and attracted the attention of Winzer, a German. Winzer could not interest Germany in the idea and went to England. Due to his efforts a part of Pall Mall was lighted in 1807, the first thoroughfare in the world to be so lighted, and in 1812, the first Gas Light and Coke Co. was established. In this country David Melville at Newport in 1806 was the first one to use gas for lighting purposes and obtained a patent for its use in 1817. Baltimore in 1817 was the first large city to use gas for lighting. It is interesting to note that in 1801 Sir Humprey Davy made the first electric-arc lamp.

At first it was necessary to have some hydrocarbons that burn with a luminous flame. In 1884, Dr. Carl Auer, began experiments on mantles to give illumination by being heated to incandescence. The famous Welsbach mantle was the result. This removed the necessity of the hydrocarbons and since that time gas has been manufactured to meet certain heat specifications. Gradually in this country the electric light has replaced gas

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for lighting purposes; but gas was ready to turn to heating purposes and is now used almost exclusively for that purpose.

The problem for the chemist in the gas plants is the production of gas from the distillation of coal, and seeing that this gas is purified and meets certain specifications for producing heat. In general the high-temperature method is used for the distillation. This gives a yield of gas consisting of methane, ethane, and hydrogen, which gives a mixture that is just above the heat value demanded. In other industries where gas is not the primary product, either of the low-temperature processes may be used. These last two methods are in a more or less experimental stage. These processes furnish a coke better suited for domestic purposes and a tar oil more like petroleum that can be cracked to yield a motor fuel with high anti-knock properties.

In brief this is how the process works in industry. The coal used is generally the Pennsylvania bituminous coal. It is placed in fire-clay retorts and heated to  $1000^{\circ}$  or  $1200^{\circ}$  C by coke fire or generator gas. This heat drives out all the gases and volatilizes all the hydrocarbons, many of them being cracked by coming in contact with walls of the retort. This increases the yield of gas and lower hydrocarbons, and deposits carbon on the walls that is collected and is used to make certain electrical appliances.

The gases are next passed into a condenser where the tar condenses in the bottom. Ammonium salts are also collected

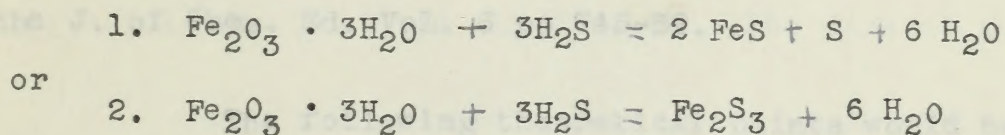
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in the condenser. Both of these products are recovered and used. The tar is sold to tar distilleries and furnishes the base for another industry. The Ammoniam is collected as a sulphate ( $(\text{NH}_4)_2 \text{SO}_4$ ) and is sold in that form. After passing through the condenser it goes to the scrubbers where it comes in contact with ammonia liquors which remove carbon dioxide ( $\text{CO}_2$ ) and hydrogen sulphide ( $\text{H}_2 \text{S}$ ). The gas goes next to the washers where it is washed with water to remove all traces of ammonia. The gas next goes to the purifiers where the last traces of  $\text{H}_2\text{S}$  must be removed to prevent the odor of  $\text{SO}_2$  after burning. This is done by passing over ferric-oxide ( $\text{Fe}_2 \text{O}_3$ )  $3 \text{H}_2\text{O}$  and the  $\text{H}_2\text{S}$  combines with it as follows:-



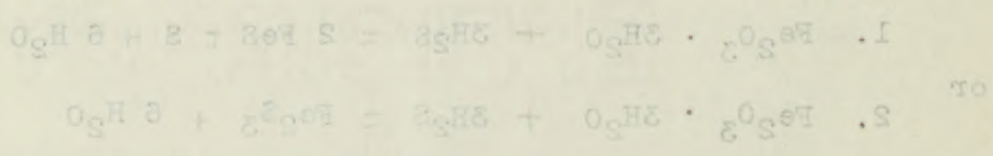
One ton of this oxide can purify ten or twelve million cubic feet of gas and can be recovered by exposing to oxygen in the air. The gas is now pure and is passed thru the station meter to the holders where it can be mixed with any gases such as water gas, which is cheaper but has less heating capacity, or blau gas from petroleum refineries that increases the calorific power. The gas is piped to the consumer from the holder.

Thus the points that should be covered by a unit on coal gas are as follows:

#### I. Consumption and use of coal gas.

- Ref. a. Pamphlet from any local Gas Co.  
 b. Figures on consumption can also be

in the condenser. Both of these products are recovered and used. The tar is sold to tar distilleries and furnishes the base for another industry. The ammonia is collected as a sulphate (NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub> and is sold in that form. After passing through the condenser it goes to the scrubbers where it comes in contact with ammonia liquor which removes carbon dioxide (CO<sub>2</sub>) and hydrogen sulphide (H<sub>2</sub>S). The gas goes next to the washers where it is washed with water to remove all traces of ammonia. The gas next goes to the purifiers where the last traces of H<sub>2</sub>S must be removed to prevent the odor of SO<sub>2</sub> after burning. This is done by passing over ferric-oxide (Fe<sub>2</sub>O<sub>3</sub>) 3 H<sub>2</sub>O and the H<sub>2</sub>S combines with it as follows:-



One ton of this oxide can purify ten or twelve million cubic feet of gas and can be recovered by exposing to oxygen in the air. The gas is now pure and is passed thru the station water to the holders where it can be mixed with any gases such as water gas, which is cheaper but has less heating capacity, or blast gas from petroleum refineries that increases the calorific power. The gas is piped to the consumer from the holder.

Thus the points that should be covered by a unit on coal gas are as follows:

- I. Consumption and use of coal gas.
- II. a. Furnished from any local gas Co.
- b. Figures on consumption can also be

obtained from same source.

## II. History of coal gas industry

- Ref. a. Miall " History of the British Chemical industry."  
b. King W. " A Treatise on Gas Manufacture."  
c. Fuel- Encyclopedia Britannica

## III. Problems of producing coal gas and actual production.

- Ref. a. Thorpe " Outline of Industrial Chemistry."  
b. Holmes " General Chemistry"  
c. Journal of Gas Lighting-Vol 59-62  
d. Homby " A Text Book of Gas Manufacture"

In the laboratory coal gas can be made. An excellent description of how this can be carried out is given by H. R. Williams (59) in " A Working Model By-Product Coke Plant." in the J. of Chem. Ed. Vol. 6 pp 745-52.

The following theoretical points would help one to understand the unit thoroughly:- flames and combustion( heat of combustion), distillation of coal, and solubility of gases.

Water gas is produced by passing steam over red-hot coke. This reaction was known in the latter part of the eighteenth century and is as follows:



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- c. Puff- "Encyclopaedia Britannica"

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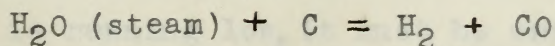
to understand the unit thoroughly:- flames and combustion (heat

of combustion), distillation of coal, and solubility of gases.

Water gas is another fuel gas that is used to some extent in this country but very little in Europe. It is cheaper to produce than coal gas but has a lower heat of combustion. It is generally added to coal gas to cheapen the cost of production and is added so as to keep the coal gas just above the heating requirements. If blau gas is available, as in Boston, some more may be added as blau gas is high above the heat requirements. It is the water gas that makes illuminating gas so poisonous. Coal gas is mainly methane ( $\text{CH}_4$ ), ethane ( $\text{C}_2\text{H}_6$ ) and hydrogen ( $\text{H}_2$ ), while water gas is hydrogen and carbon monoxide ( $\text{CO}$ ). It is the  $\text{CO}$  that is so deadly. The following figure gives some idea of the amounts of this water gas produced. In 1932 the Boston Consolidated Gas Co. produced 16,000,000 cubic feet of this gas.

There are several things being experimented on which will increase the demand for this gas. For instance the Germans have invented a method for preparing wood alcohol ( $\text{CH}_3\text{OH}$ ) from water gas by passing over a suitable catalyst. It is sold in this country as "Belgian Alcohol", and already has been able to undersell wood alcohol prepared by the destructive distillation of wood. They are also working on producing motor fuels, sugars, and other substances.

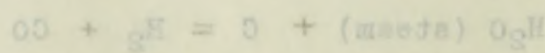
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There are several things being experimented on which will increase the demand for this gas. For instance the Germans have invented a method for preparing wood alcohol (C<sub>3</sub>H<sub>7</sub>OH) from water gas by passing over a suitable catalyst. It is sold in this country as "Belgian Alcohol", and already has been able to undergo self wood alcohol prepared by the destructive distillation of wood. They are also working on producing motor fuels, acetone, and other substances.

Water gas is produced by passing steam over red-hot coke. This reaction was known in the latter part of the eighteenth century and is as follows:



It was used commercially as early as 1824 by Ibbotson, but was not successful. The process as used by him called for the continuous passage of steam over the coke, which would cool the coke. This gave a mixture containing steam and carbon dioxide together with the hydrogen and carbon monoxide, and was poor in heat value. This process lay on the shelf until about 1875 when Lowe and duMotay in this country found that the process would be economical if not run continuously. They heated the coke by blowing air thru it. Then when the proper temperature was reached, they shut the air off and blew steam through until the coke was cooled so that a poor mixture would be obtained. The steam is then shut off and air blown through again. This procedure enables the water gas to be made economically commercially. It has since then spread and is used mostly to dilute coal gas.

The chief problem in the production of water gas is to regulate the conditions so that the reaction takes place with a satisfactory gas product. This is a case of heterogeneous equilibrium. There are several equations that may take place, but the one we desire mainly is  $H_2O + C \rightarrow H_2 + CO$ . The chemists have found out experimentally in the laboratory what the proper temperature was, and in the plant they check the product to be sure it is carried out properly.

A second problem that confronts the chemist is to enrich this gas somewhat. Its heat of combustion is quite low, and if the coal gas is running low, it must be enriched. This is done by "Carbureting" the gas and is done by "cracking" oils to give

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if the coal gas is running low, it must be enriched. This is done

by "carburettion" the gas and is done by "cracking" oils to give

lower hydrocarbons. This gives the gas a higher heat of combustion and imparts some color to the flame if it is to be used for lighting purposes. Both hydrogen and carbon monoxide burn with a nearly colorless flame.

In brief this is how the process is carried out in industry. The generator is filled with coke and heated by air blasts to about  $1100^{\circ}\text{C}$ , and is then cut off. Then superheated steam is turned on for about six minutes and blown thru the red hot coke. Six minutes is about the length of time for the reaction to cool the coke so that the proper reaction no longer takes place. Then the air blast is repeated, and so on.

The gas now goes to the carburettor. This is a chamber consisting of fire brick filled with "checker-work" of the same material. This "checker-work" is heated red hot by the gas from the air blast. This gas contains some CO and a lot of nitrogen. The CO can be burned to furnish heat and thus heats the carburettor. After being heated oil is dropped into this chamber and on hitting the red hot checker-work is cracked and enriches the water gas that is now coming into the carburettor. Thus a thousand cubic feet of water gas can be prepared from about 50 pounds of coke and 5 gallons of oil.

The hot water gas before going to a holder is generally allowed to circulate around the incoming oil to preheat that. The gas does this in passing to the superheater where the hydrocarbons from cracking are permanently fixed by heat so that

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The hot water gas before going to a holder is generally allowed to circulate around the incoming oil to preheat it. The gas does this in passing to the superheater where the hydrocarbons from cracking are permanently fixed by heat so that

they will not condense. Water gas is also purified in the same manner as coal gas before going to the final storage tank.

Thus in a unit on Water gas the following points should be touched.

#### I. Uses of water gas and amount produced.

- Ref. a. Miall " History of British Chemical Industry."  
b. Encyclopedia Britanica  
c. Figures on production can be obtained from local gas company.  
d. "Methanol Synthesis" J. Chem. Ed. Vol 3 pp 385.

#### II. History

- Ref. a. Miall " History of British Chemical Industry."  
b. Encyclopedia Britanica

#### III. The problem of water gas.

- Ref. a. Encyclopedia Britanica  
b. Royle " Chemistry of Gas Manufacture."

#### IV. Brief description of actual process in industry.

- a. Thorpe " Outlines of Industrial Chemistry."  
b. Holmes " General Chemistry."  
c. Encyclopedia Britanica  
d. Hornby " Textbook of Gas Manufacture."

If any experiment is carried out in the laboratory, great care should be exercised as the carbon monoxide is highly poisonous and has no odor. The experiment should be carried out

they will not condense. Water gas is also purified in the same manner as coal gas before going to the final storage tank.

Thus in a unit on water gas the following points should be touched.

### I. Uses of water gas and amount produced.

- a. Ref. "History of British Chemical Industry."
- b. Encyclopaedia Britannica
- c. Figures on production can be obtained from local gas company.
- d. "Methanol Synthesis" J. Chem. Ed. Vol 3 pp 385.

### II. History

- a. Ref. "History of British Chemical Industry."
- b. Encyclopaedia Britannica

### III. The problem of water gas.

- a. Ref. Encyclopaedia Britannica
- b. Roy's "Chemistry of Gas Manufacture."

### IV. Brief description of actual process in industry.

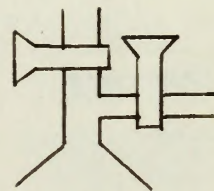
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- c. Encyclopaedia Britannica
- d. Hornby "Textbook of Gas Manufacture."

If any experiment is carried out in the laboratory, great care should be exercised as the carbon monoxide is highly poisonous and has no odor. The experiment should be carried out

under a hood.

In the experiment in the laboratory it might be well to omit the cracking of the oil or "carburettling" of the gas. A model generator would have to be made. A steel cylinder could be made having one exit at the top and two at the bottom. The top should be a screw top so that the coke could be introduced and the top replaced. One tap at the bottom should be connected to an air pump for the air blast and the other to a steam generator made up of a large flask of boiling water so that the steam can pass from there to the generator. This should be securely connected to the generator so that steam pressure can build up while the air blast is being run. The coke can be heated by flame to start and then the air blast used to continue the heating. The tube at the top should open so that the air blast can escape, and then be closed, and when the water gas comes, go out a side arm. It should look like this. The air blast

should not be long so that too much pressure would be built up in the steam generator. These blasts can be alternated as long as desired.



After the gas is produced, it should be treated in a manner similar to that mentioned for coal gas. Extreme care must be utilized throughout the entire experiment.\*

The theoretical points will be similar to those for coal gas except that the conditioning of the reaction is necessary here as the whole industry hinges on it.

\*A very dangerous experiment. See discussion of Laboratory procedure on Pages 161-62.

under a hood.

In the experiment in the laboratory it might be well to call the circulation of the oil or "carburizing" of the cast. A local generator would have to be made. A steel cylinder could be made having one exit at the top and two at the bottom. The top should be a series of holes so that the steam could be introduced and the top raised. On top of the bottom should be connected to a glass tube for the air to be drawn into a steam generator. A large flask of boiling water so that the steam can pass through the generator. This should be carefully connected to the generator so that steam pressure can build up while the air glass is being run. The glass can be heated by flame to start and then the air glass used to continue the heating. The tube at the top should be so that the air glass can escape, and when it is closed and when the water is over, to put a side arm. It should look like this. The air glass should not be heavy so that too much pressure would be built up in the steam generator. These glass can be air heated as long as desired.



After the glass is prepared it should be treated in a manner similar to that mentioned for some time. Extreme care can be utilized through-out the entire experiment.

The apparatus described is also suitable for the study of the reaction of the steam with iron.

A very thorough experiment. The discussion of laboratory procedure is given in the text.

UNIT ON TAR

Tar is a black, viscous liquid with an unpleasant odor. In looking at tar one would never imagine that it had much use, yet from it come innumerable substances. Tar itself does not contain these products, yet they furnish the materials that are the crude products for the other industries. Tar of course is used a great deal on roads as every one knows. It is used in making roofing paper and pitch as many know. But from it are also obtained benzene, toluene, phenol, cresol, naphthalene, anthracene, methyl anthracene, phenanthrene, and carbazol. These materials are used to make drugs, dyes, explosives, flavors, perfumes, and many other products. Slosson in his creative chemistry has a chart that shows the many products that can be obtained from coal tar.

The following figures show the amounts of material produced from coal tar and are taken from page 359 of the World Almanac. All figures represent pounds.

<u>Year</u>	<u>Intermediates</u>	<u>Dyes</u>	<u>Syn. Resins</u>	<u>Color Lakes</u>	<u>Medicinals</u>	<u>Perfumes</u>	<u>Flavors</u>	<u>Total</u>
1925	210,699,799	86,345,438	14,687,074	11,414,753	3,237,796	2,335,024	2,207,102	120,554,228
1926	229,653,802	87,978,624	14,106,993	11,796,203	3,696,196	1,992,666	2,857,913	122,753,021
I 927	240,073,184	95,167,905	18,784,713	11,601,507	3,598,839	1,998,987	2,205,472	133,191,969
1928	279,274,807	96,625,451	26,998,966	12,127,242	4,008,393	1,577,718	1,746,350	143,563,099
1929	354,487,718	111,421,505	33,036,490	13,244,676	5,000,205	1,599,430	2,292,450	167,175,703
1930	290,760,532	86,480,000	30,867,752	9,563,318	7,501,970	1,042,232	1,910,012	137,465,284

The following figures represent the amount of tar used for other purposes and are taken from the 15th Census of the U. S. A. Vol II. on Manufactures.

<u>Year.</u>	<u>Total Gal. of Tar. Produces.</u>
1929	345,794,885 Gal.
1927	730,558,244 Gal.



Thus we see tar is used in many different ways and many places.

Tar has been known as long as coal gas has been known but was considered as a nuisance. It was obtained in the purification of coal gas along with ammoniacal liquors but was emptied into the rivers. In this country complaints were made about this so that it was saved and given to boys for their fourth of July bonfires. In England some use was made of it fairly early. A distillery was erected by Accum in 1815. Another was erected at Firth in 1822 and sold the light oils to Mr. Mackintosh to be used for waterproofing. Then the heavy oils (creosote oil) was collected and used for creosoting wood and the pitch used for various purposes. Leigh and Hoffman showed about this time that various substances were contained in these fractions but there was not much demand for them.

In the latter part of the 19th century a number of things were discovered which produced a greater demand for tar products. The first was the development of synthetic dyes that demand tar products for their start. In 1856 Perkins in England discovered mauve, the first dye to be made synthetically. It was found by accident, as many things are, because one of the reagents he used was impure. Others were soon found, madder being made in 1869, and indigo in 1880. These dyes demand benzene toluene, and the others as their starting point.

Shortly after the dye industry started the synthetic

That we expect is used in very little way

and many places.

It has been known as long as I can remember that the

industry of coal was long with somewhat different

of July 1875. In England some are the same as in Italy

early. A similar industry was started by about 1815.

started at first in 1802 and sold the first lot to the

to be used for transportation. Then the heavy duty

was collected and used for transportation wood and steel used

for various purposes. Coal and oil were about the same

that various purposes were contained in these sections but

there was not much demand for them.

In the latter part of the 19th century a number

of things were discovered which showed a greater demand for

the product. The first was the development of synthetic gas

which showed the necessity for their use. In 1855 Britain

perfumes and flavors followed. Perkins found and made cumarin in 1868. Piermann made vanillin in 1874. The drug business followed next. Salicylic acid and phenol were found before the dyes started; but it was not until 1886 that acetanilide was made, and aspirin followed in 1899.

This country was content to obtain these synthetic products from Europe. When the world war broke out in 1914 there were only seven firms employing only 528 men in existence, in this country. Under the impetus of the war these products expanded greatly until now instead of importing these products we export them. Before the war a great majority of the coke was made in bee-hive ovens and all the volatile matter escaped into the air. Now practically all coke is made in by-product coke ovens and the tar is collected and used. This has brought many dollars to this country instead of our losing money by importing.

The problem for the tar plant consists mainly in one of distillation. Most of the products are distilled from the tar in fractions, and these fractions are further separated by further distillation or crystallization. The chemist must see that the fractions separated from the tar are proper. Then he must see to it that the final products are pure enough to meet specifications set for them.

In this unit we will content ourselves with describing how road tars are made, and how naphthalene and phenol are separated. These are two of the most important products from tar.

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In this unit we will content ourselves with describ-  
ing how road tars are made, and how naphthalene and phenol are sep-  
arated. These are two of the most important products from tar.

The tar is loaded into tar stills and heated. For road tars the specifications generally consist of the tar having so much water, so much oil, and a certain viscosity. This can be generally met by running off so much of the oil contained in the tar. For instance it may be found in the laboratory that if 20% of the oil is run off, the tar will meet the specifications. Then the tar is distilled until 20% of the oil is run off and the still only kept warm, ----- if it then tests up to standard, it can be pumped to storage tanks or directly to the tank cars used to ship it.

If the tar is to be run for its products, the tar is run to pitch and the distillate separated into fractions. There are generally five fractions, which are as follows: -

1. First runnings or "light oil" to 105C
2. Light oil to 210 C
3. Carbolic oil to 240 C
4. Creosote oil to 270 C
5. Anthracene oil above 270 C

The still is run until the distillate is gummy. It is then stopped and allowed to cool a few hours and then run out to form hard pitch.

The carbolic oil contains phenol and is pumped to the cresylic acid plant for extraction. Here it is treated with caustic soda to form carbolate. The carbolate is soluble in water and the neutral oil floats on top and is removed. The carbolate

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 generally met by running off so much of the oil contained in the  
 tar. For instance it may be found in the laboratory that if 20%  
 of the oil is run off, the tar will meet the specifications. Then  
 the tar is distilled until 80% of the oil is run off and the still  
 only kept warm, ---- if it then tests up to standard, it can  
 be pumped to storage tanks or directly to the tank cars used to  
 ship it.

If the tar is to be run for its products, the tar  
 is run to pitch and the distillate separated into fractions. There  
 are generally five fractions, which are as follows: -

1. First runnings or "light oil" to 1080
2. Light oil to 210 C
3. Carbolic oil to 240 C
4. Grease oil to 270 C
5. Asphaltene oil above 270 C

The still is run until the distillate is heavy.  
 It is then stopped and allowed to cool a few hours and then run  
 out to form hard pitch.

The carbolic oil contains phenol and is pumped to  
 the cresylic acid plant for extraction. Here it is treated with  
 caustic soda to form cresolate. The cresolate is soluble in water  
 and the neutral oil floats on top and is removed. The cresolate

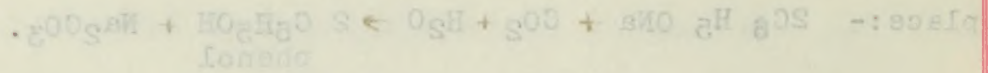
then has steam blown through it so that any oil, naphthalene, and pyridine will steam distill out. When all is removed, the carbolate is destroyed and the crude carbolic acid regenerated by passing carbon dioxide thru the carbolate. The following reaction takes place:-

$$2\text{C}_6\text{H}_5\text{ONa} + \text{CO}_2 + \text{H}_2\text{O} \rightarrow 2\underset{\text{phenol}}{\text{C}_6\text{H}_5\text{OH}} + \text{Na}_2\text{CO}_3.$$

The carbolic acid is insoluble in the water solution and can be drawn off. It is washed with sulphuric acid to destroy any carbonate left in the acid and then washed with water to remove acid. This leaves crude carbolic acid and consists of phenol, cresols and xylenols. This is run to a still (generally vacuum), and the phenol is fractionated off giving a pure white crystal that melts about 104° F. The phenol prepared this way is used almost exclusively for making plastics.

Some naphthalene is present in the neutral oil from the cresylic acid plant and there is much in the cresote oils. These are cooled until the naphthalene crystallizes out. This is filtered off giving us our crude naphthalene. This is washed, in caustic soda and sulphuric acid to remove any cresylic acid and oil. Then the naphthalene is sent to the flake house and sublimed. With a little heat a great deal of naphthalene is transformed to vapor which condenses to crystals again on striking a cool surface. This gives us the pure naphthalene. If it is used as moth balls, it is generally run to that form. If not it is often packed in barrels as chips or flake, depending on which form is desired.

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Some naphthalene is present in the neutral oil from the creosote plant and there is much in the creosote oils. These are cooled until the naphthalene crystallizes out. This is filtered off giving us our crude naphthalene. This is washed in caustic soda and sulphuric acid to remove any creosote acid and oil. Then the naphthalene is sent to the lake house and sublimed. With a little heat a great deal of naphthalene is transformed to vapor which condenses to crystals again on striking a cool surface. This gives us the pure naphthalene. If it is used as moth balls, it is generally run to that form. It is often packed in barrels as chips or flakes, depending on what form is desired.

In a unit on tar, then, the following points should be covered.

I. Tar and its products and uses.

- Ref. a. Slosson "Creative Chemistry" - Revised  
b. World Almanac  
c. 15th Census of U.S.A. Vol II Manufactures.

II. History of Tar

- Ref. a. Miall "History of British Chemical Industry."  
b. Slosson "Creative Chemistry"  
c. Warnes "Coal Tar Distillation."

III. Problems of road tar and preparation.

- Ref. a. Thorpe "Outlines of Industrial Chemistry."  
b.

IV. Problems of phenol and preparation.

- Ref. a. Thorpe "Outlines of Industrial Chemistry."  
b. Lunge "Coal Tar and Ammonia."  
c. Warnes "Coal Tar Distillation."

V. Problems of naphthalene and preparation.

- Ref. a. Same as for phenol.

In the laboratory, the tar can be distilled and naphthalene and phenol separated. Two or five gallons of crude tar can be obtained from the local gas works or some company such as the Barrett Co. A big 5 liter flask can be set up and arranged as a distillation flask by connecting a condenser into it thru a cork and placing a 400° C thermometer into the cork. The fractions can be separated by replacing the catch flask with a

In a unit on tar, then, the following points should

be covered.

I. Tar and its products and uses.

Ref. a. Slosson "Creative Chemistry" - Revised

b. World Almanac

c. 1934 Census of U.S.A. Vol II Manufactures.

II. History of Tar

Ref. a. Mill "History of British Chemical Industry."

b. Slosson "Creative Chemistry"

c. Warner "Coal Tar Distillation."

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IV. Problems of phenol and preparation.

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c. Warner "Coal Tar Distillation."

V. Problems of naphthalene and preparation.

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In the laboratory, the tar can be distilled and

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tar can be obtained from the local gas works or some company such

as the Barrett Co. A big 5 liter flask can be set up and arranged

as a distillation flask by connecting a condenser into it thru

a cork and placing a 400° C thermometer into the cork. The

fractions can be separated by replacing the carbon flask with a

new one when the thermometer reaches the appropriate temperature. The last fraction should be run to about 350° C and the pitch poured out into a mold and allowed to harden. This can be tested out as a fuel.

The carbolic or acid oil can be shaken up with caustic and the carbolate removed. Just boiling the carbolate should remove oil, pyridine, and naphthalene. A carbon dioxide generator can be set up by placing marble chips in a flask and allowing hydrochloric acid to drop on them. The resulting gas can be passed through the carbolate until the acid is "sprung". It should be treated with acid to remove any alkali and washed to remove acid. The phenol can then be separated by fractional distillation using a fractionating column with an air condenser. Fairly pure phenol should be prepared.

The creosote oil can be chilled with an ice and salt solution and the naphthalene filtered off. The excess oil should be centrifuged off. The naphthalene should then be melted and washed with caustic and acid, and on washing out the acid it can be given its last treatment by either distilling or sublimation. In distilling, the first and last 10% should be rejected. In sublimation the naphthalene can be placed in a beaker and warmed gently. The flakes can be collected on a water cooled plate and scraped off.

Materials needed are listed on following page.

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can be given its last treatment by either distilling or sublimation.  
In distilling, the first and last 10% should be rejected. In sub-  
limation the naphthalene can be placed in a beaker and warmed  
gently. The flask can be collected on a water cooled plate and  
scrapped off.

Materials needed are listed on following page.

- |                            |                      |
|----------------------------|----------------------|
| 1. 1-5 liter flask         | 1. 5 gal. crude tar. |
| 2. 1-condenser (straight)  | 2. Bunsen burners    |
| 3. 1-fractionating column. | 3. Caustic soda      |
| 4. 1-400° C thermometer    | 4. Sulphuric acid    |
| 5. 1-175-230° C "          | 5. Marble chips.     |
| 6. 1-0-100° C "            |                      |
| 7. Glass tubing.           |                      |
| 8. Flasks and beakers.     |                      |

Both the phenol and naphthalene should be tested for purity by determining the freezing point.

The following theoretical points would help one to understand a unit on tar:- acids vs. bases, crystallization and solubility, distillation (straight, fractional, and steam); and some theory can be illustrated on the determination of purity by freezing point.

1. 5 gal. crude tar
2. Bunsen burners
3. Caustic soda
4. Sulphuric acid
5. Marble chips

1. 1-5 liter flask
2. 1-condenser (straight)
3. 1-fractionating column
4. 1-400 C thermometer
5. 1-175-230 C "
6. 1-0-100 C "
7. Glass tubing
8. Flasks and beakers

Both the phenol and naphthalene should be tested for purity by determining the freezing point.

The following theoretical points would help one to understand a unit on tar: - acids vs. bases, crystallization and solubility, distillation (straight, fractional, and steam); and some theory can be illustrated on the determination of purity by freezing point.

## UNIT ON PLASTICS

Plastics are a new set of compounds that have recently sprung into existence and are rapidly growing. Their chief representatives are celluloid and the phenol condensation resins that are sold under various names such as bakelite. These substances are used to make cups, saucers, bowls, ashtrays, electrical apparatus, and many imitation things such as tortoise shell. At present, the size of this industry is not as large as some of the others we have mentioned, but the following figures show how large it is. These are taken from page 359 of the World Almanac and represent the amounts of resins made from phenol condensation.

<u>Year.</u>	<u>Synthetic Phenol Resins</u>
1925	14,687,074 pounds
1926	14,106,993
1927	18,784,713
1928	26,998,966
1929	33,036,490
1930	30,867,752

Miall in the "History of the British Chemical Industry" estimated the production of the world of this type as 25000 tons in 1930, so we see the United States produces a large portion of the world's supply.

The celluloid type was the first type to be discovered. As early as 1855 Parkes in England was working on the question but was forced to give it up. Spill followed him and turned out a better product, but not celluloid. Hyatt, an American, found the right answer, and again by accident. He was a printer originally but turned to the idea of making artificial ivory for billiard balls, as a \$ 10,000 prize was offered. He heard of the

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Year	Synthetic Phenol Resins (pounds)
1935	14,687,074
1934	14,108,993
1933	13,784,713
1932	13,036,985
1931	12,038,490
1930	10,887,782

Half in the "History of the British Chemical Industry" estimated the production of the world of this type as 28000 tons in 1930, so we see the United States produces a large portion of the world's supply.

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work of the Englishmen but not accurately. They had tried mixing camphor and guncotton together with castor oil as a solvent. Hyatt didn't know about the castor oil and just mixed the two together. On heating under pressure, he obtained celluloid. He found it could be moulded into any desirable form, and in 1872 he started a plant at Newark, N. J. to manufacture celluloid. However, it wasn't until about 1918 that he succeeded in making his artificial billiard balls. This type of resin has several draw backs. It is highly inflammable; it smells of camphor; it is attacked by acids and alkalies; and it softens on being heated.

The condensation resins are much more recent but the key has been in the hands of chemists for a long time. Every now and then in old research papers the following statement is found: "The reaction resulted in nothing but an insoluble resin which was not further investigated". This, however, is the basis of our condensation resins. In 1909 Baekeland, a Belgian, undertook a systematic study of one of these resins (the one formed by the condensation of formaldehyde and phenol). He found that if the resin were heated under pressure, a hard infusible, and insoluble kind of resin was now formed. This resulted in the General Bakelite Co. being erected at Perth Amboy, N.J. This resin does not have the bad points of the celluloid, but it can not be made clear and transparent.

The problem confronting the chemist in the plastics is to make a resin that is hard and can be formed into substances required. He knows that if certain things are done, he gets his

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The problem confronting the chemist in the plastic

is to make a resin that is hard and can be formed into substances

required. He knows that if certain things are done, he gets his

resins, and these conditions are what are chemically controlled. Just what the composition of his resin is and why it occurs he does not know. He explains it by polymerization. This is what is said to occur when several molecules present unite with each other to form a larger molecule or "merger". We have several other examples of polymers such as starch and cellulose.

The actual plant operations in back of these processes are simple. In the celluloid branch, the collodion-cotton and camphor are worked together in alcohol to give a tough pasty mass. It is then worked in steam heated machines which cause the alcohol to evaporate and be recovered by condensing it from the air. The hot mass is screened to remove dirt, undissolved fibres, and lumps. It is then worked under steam heated rollers to remove the last traces of the alcohol and any air bubbles. Any coloring material is added here. At the end of this, thin colored films are produced that can be pressed together to give any desired thickness required. These thick slabs can be machined to give any shaped final object required.

The condensation resins are formed in steps. Bakelite has three forms, A, B. and C., the C form being the desired one. Here formaldehyde and phenol in the presence of a condensing agent are refluxed until resin A is formed which fuses at 170°C without decomposition. This resin is allowed to cool in pans and sent on to the next step. Here it is ground and mixed with dyes and a weight material, such as wood meal. When thoroughly mixed, this powder is put in moulds and heated under pressure to form B and then C which

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cesses are simple. In the celluloid branch, the cellulose-ester  
and camphor are worked together in alcohol to give a tough paste  
mass. It is then worked in steam heated machines which cause the  
alcohol to evaporate and be recovered by condensing it from the  
air. The hot mass is screened to remove dirt, undissolved fibres,  
and lumps. It is then worked under steam heated rollers to remove  
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shaped final object required.

The condensation resins are formed in steps. Benzoin  
has three forms, A, B, and C, the C form being the desired one.  
Here formaldehyde and phenol in the presence of a condensing agent  
are refluxed until resin A is formed which fuses at 170°C without  
decomposition. This resin is allowed to cool in pans and sent on  
to the next step. Here it is ground and mixed with dyes and a wetting  
material, such as wood meal. When thoroughly mixed, this powder is  
put in moulds and heated under pressure to form B and then C which

is unfusible, insoluble, and does not become plastic on heating. If desired, the A form, when dissolved in a suitable solvent, forms an insoluble and brilliant varnish.

Thus in a unit on Plastics the following points should be considered.

I. Production (amounts and uses)

- Ref. A. Miall "History of British Chemical Industry".  
B. Slosson "Creative Chemistry" - Revised  
C. World Almanac

II. History of Development of Industry.

- Ref. A. Miall "History of British Chemical Industry"  
B. Slosson "Creative Chemistry" - Revised  
C. J. S. C. I. 1914 p 225  
D. Pamphlet from Bakelite Corporation or any other company.

III. Brief description of plant operation

- Ref. A. Thorpe "Outlines of Industrial Chemistry"

IV. The problem of Polymerization for Plastics.

- Ref. A. Slosson's "Creative Chemistry" - revised  
B. Moore's "Outlines of Organic Chemistry"

In the laboratory both types of plastics could be illustrated. Collodion cotton can be made by dissolving nitro-cellulose in alcohol and ether, and evaporating to a paste. This can be mixed with camphor dissolved in alcohol. The alcohol can be allowed to evaporate and the resulting paste put in a die, placed in a vise and carefully heated.

This should give an article made of celluloid.

In the condensation resin, phenol, formaldehyde, and the condensation material can be mixed and refluxed in an

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Thus in a unit on plastics the following points should

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B. Sisson "Creative Chemistry" - Revised  
C. World Almanac
- II. History of Development of Industry.  
Ref. A. Meil "History of British Chemical Industry".  
B. Sisson "Creative Chemistry" - Revised  
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In the laboratory both types of plastics could

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can be mixed with camphor dissolved in alcohol. The alcohol can  
be allowed to evaporate and the resulting paste put in a die,  
placed in a vise and carefully heated.

This should give an article made of celluloid.

In the condensation resin, phenol, formaldehyde,

and the condensation material can be mixed and refluxed in an

ordinary flask with a reflux condenser attached. The A resin can be ground and mixed with a dye and wood meal, and placed in a crude die. This can be placed in a vise and heated. The two resins should be compared. Some of the A resin should be dissolved in alcohol and applied as a varnish to show what this is like.

Materials needed are as follows:

- |                         |                                    |
|-------------------------|------------------------------------|
| 1. Beakers              | 1. Cotton                          |
| 2. A crude die          | 2. Nitric acid                     |
| 3. Vise                 | 3. Alcohol                         |
| 4. 1 - one liter flask  | 4. Ether                           |
| 5. 1 - reflex condenser | 5. Phenol                          |
|                         | 6. Formaldehyde                    |
|                         | 7. Condensation agent of some sort |
|                         | 8. Dye                             |
|                         | 9. Wood meal                       |

The only theoretical point that should be really understood here is that of polymerization and conditions affecting it. This would allow the pupil to understand quite thoroughly the unit.

Paper was known to the Chinese in the second century B.C., but its use did not spread much until 751 A.D. when at the battle of Tashkent, the Arabs captured some Chinese paper makers who showed the art to the Arabs. An Arab m.a. has been found of paper dating to the 9th century. Most of this paper was made from flax. Paper passed to the Greeks in the 11th century and to the Arabs in the 12th century. The first mention of rag paper is found in a discourse by Peter, Abbot of Clug (1182-1180). Other sources of material for transcribing writing were wax tablets by the Greeks, and parchment by the Romans. The parchment that was finally

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|------------------------------------|-------------------------|
| 1. Cotton                          | 1. Beakers              |
| 2. Nitric acid                     | 2. A crude die          |
| 3. Alcohol                         | 3. Vise                 |
| 4. Ether                           | 4. 1 - one liter flask  |
| 5. Phenol                          | 5. 1 - reflux condenser |
| 6. Formaldehyde                    |                         |
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| 8. Dye                             |                         |
| 9. Wood meal                       |                         |

The only theoretical point that should be really understood here is that of polymerization and conditions affecting it. This would allow the pupil to understand quite thoroughly the unit.

## UNIT ON PAPER

Paper is used to convey our thoughts and to record them so that they may pass from one generation to another. Books are made of paper and we obtain much of our knowledge from books. We learn of current events and what is happening in all fields by reading newspapers made of paper. It was not until paper was made and made cheaply that knowledge became common. The paper industry in this country has risen to large proportions. The following figures show how much is produced annually in this country. The figures represent tons produced in 1926 and are taken from the Encyclopedia Britannica.

<u>Country</u>	<u>Tons of Paper Produced</u>
United States	10,002,070 tons
Germany	2,008,000
Canada	2,266,143
Great Britain	1,600,000
Japan	808,140
Russia	641,098
Norway	635,077
Sweden	598,020
Finland	566,950

Paper was known to the Chinese in the second century B.C., but its use did not spread much until 751 A.D. when at the battle of Samakand, the Arabs captured some Chinese paper makers who showed the art to the Arabs. An Arab m.s. has been found on paper dating to the 9th century. Most of this paper was made from flax. Paper passed to the Greeks in the 11th century and to the Moors in the 12th century. The first mention of rag paper is found in a discourse by Peter, Abbot of Cuny (1122-1150). Other sources of material for transcribing writing were wax tablets by the Greeks, which were perishable, papyrus of the Egyptians that was fragile.

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Parchment was expensive and penning was slow.

By the 14th Century paper had come into use for all literary purposes, and in the next superseded vellum. Blotting paper was first made in 1465 and brown paper in 1570-1. In England John Tate had a mill for making paper. However, with the coming of the printing press in 1446 we find a gradual increase in the demand for paper. The first mill in this country was at Germantown in 1690. The first in Massachusetts was in 1728 at Milton.

With the advent of newspapers and magazines there was again an increase in the demand for cheap paper. Rags and linen had been the chief source of paper until 1866<sup>when</sup> esparto grass was introduced and about twenty years later wood pulp was introduced. Now nearly all paper is made from wood pulp, and the demand is tremendous. One New York paper used nearly 2000 acres of forest a year. In the meantime machinery was replacing hand made paper. A Frenchman, Roberts, was the first one to use it in 1798 and Four-grinier and Doukin introduced it to England in 1803. Most of the improvements since 1890 have been in the preparation of the wood pulp from the trees.

The problem for chemistry in the paper industry is to make a filtered web, fabric, or tissue of cellulosic fibres. The problem in making the paper is highly mechanical but presents some problems for the chemist, one of which is sizing the paper to prevent the absorption and consequent spreading of ink. This is

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pulp from the trees.

The problem for chemistry in the paper industry is to

make a filtered web, fabric, or tissue of cellulose fibres. The

problem in making the paper is highly mechanical but presents some

problems for the chemist. One of which is sizing the paper to

prevent the absorption and consequent spreading of ink. This is

accomplished by adding a material such as gelatine, that fills the small pores in the paper and so "sizes" it.

In the actual plant operation the sources of paper, wood pulp, rags, etc. are charged in the hollander and water added and the whole mass agitated until the fibres are thoroughly separated. Loading material such as Kaolin to give the paper weight and smoothness, and size are added and thoroughly mixed. When thoroughly separated into fibres the pulp is carried out by water, any lumps being left behind, and is carried to the paper making machine. The Fourdrinier machine is often used. The pulp flows onto an endless wire gauge belt that is given sideways shaking motion and felts the pulp while the water drains away. There are suction boxes under the belt that also tend to draw the water away. The web is next transferred to an endless blanket that carries it between squeeze-rolls, and then to a second one. From there it goes to a series of steam heated calendars that dry the paper and set the size. With the Fourdrinier machine the water mark is placed in the paper by a "dandy roll" between the suction boxes that leaves an impression on the soft pulp.

Various types of paper are made by varying the source of pulp. Paper for newspapers is made of wood pulp and heavily loaded. Wrapping paper is made from unbleached straw, hemp and colored rags. Blotting paper is unsized paper, Tissue paper is also unsized but made from the long fibres of hemp and cotton. Writing paper is made from the best materials and highly sized.

Therefore, in a unit on paper the following points

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should be considered.

I. Importance of paper and amounts produced.

- Ref. a. Slosson "Creative Chemistry" revised  
b. World Almanac  
c. Pupil observations

II. History of paper

- ref. a. Encyclopedia Britanica  
b. Slosson "Creative Chemistry" revised  
c. Watt "The Art of Paper Making"

III. Problem and Production of paper

- ref. a. Thorpe "Outlines of Industrial Chemistry"  
b. Cross and Bevan "A Testbook of Paper Making"  
c. Watt "The Art of Paper Making"  
d. The Paper Trade Journal

In the laboratory it may be rather hard to make paper satisfactorily, but I think some success may be obtained if the following method is used. Some wood pulp or cotton rags can be thoroughly digested in hot water and thoroughly cut up. Some Kaolin and gelatine can be added and thoroughly mixed. This, thoroughly mixed, can be poured with hot water into a chute that leads onto some screening made into an endless belt that travels over two hand turned rollers. This would allow the water to drain off. It might be possible to place some sort of suction under the web by topless cylinders hitched to an ejector with a valve underneath so as to drain out water at intervals. The paper should only be made

should be considered.

I. Importance of paper and amounts produced.

- Ref. a. Slosson "Creative Chemistry" revised
- b. World Almanac
- c. Pulp observations

II. History of paper

- ref. a. Encyclopedia Britannica
- b. Slosson "Creative Chemistry" revised
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two or three inches wide. This could be transformed to an endless felt roller by bringing the felt roller very close to the second roller on the endless screen.

On the felt belt it should pass thru two or three rollers to squeeze water out of it. The problem is to get heated calendars to dry the paper and set the size. It might perhaps be best to set up several rollers in a sort of furnace that can be heated, or to have the rollers carefully heated from below by bunsen burners. The hot water should not be too hard to evaporate. The ideal situation would be if some of the pupils could make some hollow rollers thru which steam could be passed so as to make calendars. A series of these rollers should be placed close together and the wet pulp run between them until dry. This should give a fairly good sort of paper. If the run is successful, another could be made with no size<sup>ing</sup> and the two compared to show the necessity for sizing.\*

Materials needed would be as follows:

- |                   |                   |
|-------------------|-------------------|
| 1. Beakers        | 1. Wood pulp rags |
| 2. Rollers        | 2. Kaolin         |
| 3. Shute          | 3. Gelatine       |
| 4. Source of Heat |                   |
| 5. Screening      |                   |

The only theoretical point to be explained in this unit is capillary attraction of the pores of the paper, involving the necessity for sizing to prevent the spread of ink.

\* The quality of product is doubtful. See discussion on Laboratory procedure on Pages 161-62.

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give a fairly good sort of paper. If the run is successful, another  
could be made with no size and the two compared to show the necessity

for sizing.\*

Materials needed would be as follows:

- |              |                   |
|--------------|-------------------|
| 1. Wood pulp | 1. Sizers         |
| 2. Kaelin    | 2. Rollers        |
| 3. Cellulose | 3. Shims          |
|              | 4. Source of heat |
|              | 5. Sizing         |

The only theoretical point to be explained in this  
unit is capillary attraction of the pores of the paper, involving  
the necessity for sizing to prevent the spread of ink.

\* The quality of product is doubtful. See discussion on  
Laboratory procedure on pages 101-102.

## UNIT ON COTTON

Cotton is a vegetable fibre from which a great deal of our clothing is made. It is used to make pure fabrics and is also mixed with wool, rayon, and silk. Such articles as stockings, underwear, shirts, dresses etc. are made from cotton. Thus it furnished a great deal of the clothing we wear. The following figures taken from the 15th Census of the United States Vol 2 Manufacturers show how much we use annually.

Year	1929	1927	1925
Pounds of Woven Goods	2,363,404,826	2,433,709,519	2,070,985,006

Cotton has been used for a long time as a fabric. Its early home was in India where it was used extensively for clothing. From India it was carried by travellers to Egypt. After the discovery of America it was brought to this country where it thrived. America produces probably the best cotton in the world, the famous Sea Island cotton. The chief home for cotton is the warm climates.

Commercially the cotton industry was not very extensive until a cheap cotton and plenty of it could be obtained. The seeds had to be removed by hand, which was a slow and laborious process. Hence not much was produced and the price was fairly high. In 1783 Eli Whitney invented the cotton gin and a large cotton industry was the result. By this machine the cotton was quickly rid of its seeds. This increased the amount of cotton that could be put on the market and as machinery was beginning to appear in the mills the cotton industry received a tremendous boost. During the recent World War there was a tremendous demand

Cotton is a vegetable fibre from which a great deal of our clothing is made. It is used to make pure fabrics and is also mixed with wool, rayon, and silk. Such articles as stockings, underwear, shirts, dresses etc. are made from cotton. Thus it furnished a great deal of the clothing we wear. The following figures taken from the 18th Census of the United States Vol 2 Manufacturers show how much we use annually.

Year	1929	1927	1925
Pounds of Woven Goods	2,365,404,822	2,443,708,819	2,070,222,000

Cotton has been used for a long time as a fabric. Its early home was in India where it was used extensively for clothing. From India it was carried by travellers to Egypt. After the discovery of America it was brought to this country where it thrives. America produces probably the best cotton in the world, the famous Sea Island cotton. The chief home for cotton is the warm climates. Commercially the cotton industry was not very extensive until a cheap cotton and plenty of it could be obtained. The seeds had to be removed by hand, which was a slow and laborious process. Hence not much was produced and the price was fairly high. In 1783 Eli Whitney invented the cotton gin and a large cotton industry was the result. By this machine the cotton was quickly rid of its seeds. This increased the amount of cotton that could be put on the market and as machinery was beginning to appear in the mills the cotton industry received a tremendous boost. During the recent World War there was a tremendous demand

for cotton and many plants were erected; but after the war these plants tried to keep on running, and the industry began to suffer from over-production. It is also interesting to note the shift of the cotton centers in this country. At first all the manufacturing plants were in New England, but now the plants are moving south.

The seeds from the cotton were for a long time thrown away as useless. However, the chemist hates to see anything go to waste, so he began to look around for uses for it. He found that the seeds contained an oil which could be extracted. Then he found that this oil could be used as an edible oil, a lubricant, or for making soap. He found that on treating it with hydrogen he could make a fat that could be substituted for lard. These products were hard to get on the market as everyone seems to desire to use the old tried substances, but now huge amounts of cottonseed oil are used as is shown by the following figures for its production. These figures are taken from the 15th Census of the United States Vol II Manufactures.

Year	1929	-	1927	-	1925
Cottonseed Oil	1,604,131,038 lbs.	-	1,887,910,155 lbs.	-	1,617,014,701 lbs.
Coke & Meal	2,281,576 tons		2,840,084 tons		2,596,715 tons

After the oil was extracted, the chemist found he now had a mash left, and what could he do with this? He investigated and found it could be used as a cattle food. So now we use the cotton fibres to make cloth, extract oil from the seed, and use

for cotton and many plants were evicted; but after the war these plants tried to keep on running and the industry began to suffer from over-production. It is also interesting to note the shift of the cotton centers in this country. At first all the manufacturing plants were in New England, but now the plants are moving south.

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Year	1929	1927	1925
Cottonseed Oil	1,504,131,038 lbs.	1,887,910,155 lbs.	1,517,014,707 lbs.
Coke & Gas	2,281,576 tons	2,840,084 tons	2,038,715 tons

After the oil was extracted, the chemist found he now had a mash left, and what could he do with that? He investigated and found it could be used as a cattle food. So now we use the cotton fibres to make cloth, extract oil from the seeds, and use

the remaining meal as a cattle food so that none of the cotton is lost.

In the manufacture of cotton cloth the problem for the chemist is to find and use means to purify or rather, cleanse and to bleach cotton by chemicals that are not injurious to the fibre. In the oil end, it is to extract and purify all the oil that can be obtained from the seeds.

The cotton fibre consists essentially of cellulose enclosed in a film or skin. On the surface is a waxy or oily material that must be removed before dyeing. Now mineral acids except nitric ( $\text{HNO}_3$ ) destroy the fibres.  $\text{HNO}_3$  forms nitrate derivatives such as guncotton and nitrocellulose. Thus we can not use mineral acids for cleaning the fibres. Alkalies are not as injurious. In fact a proper treatment is an aid to the yarn. John Mercer found that cotton when treated with a dilute caustic soda solution, had stronger, glossier, and better dyeing fibres, and a great deal of cotton cloth is now mercerized. So we see that to clean the cloth we must use alkalies. This is generally done just before bleaching.

In mercerizing, the cotton fabric is run thru a dilute caustic soda solution ( $50^\circ\text{Tw}$ ) under tension. The cloth is wet first to insure even action on the fibre. Then it is rinsed in water and then run thru a bath of dilute acetic or sulphuric acid ( $.5 \text{ Be}^\circ$ ) to neutralize the caustic, washed and dried.

In bleaching cotton goods they are first singed by

the remaining meal as a cattle food so that none of the cotton is lost.

In the manufacture of cotton cloth the problem for the chemist is to find and use means to purify or rather, cleanse and to bleach cotton by chemicals that are not injurious to the fibre. In the old days, it is to extract and purify all the oil that can be obtained from the seeds.

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In mercerizing, the cotton fabric is run thru a dilute caustic soda solution ( $50^\circ\text{Tw}$ ) under tension. The cloth is wet first to insure even action on the fibres. Then it is rinsed in water and then run thru a bath of dilute caustic or sulphuric acid ( $1.8 \text{ Be}^\circ$ ) to neutralize the caustic, washed and dried.

In bleaching cotton goods they are first stained by

passing over a row of Bunsen burner flames. This burns away lint, floss, and loose hairs that would prevent the printing of a sharp design. The goods are then wet and allowed to soak overnight to loosen starchy material. Milk of lime and water are added the next day. Then the cloth is boiled. The milk of lime makes lime soaps with the fatty material and dissolves the other materials. It is then washed with water and passed to the "First sour". Here it is treated with dilute  $H_2SO_4$  to remove iron stains and metallic oxides. The goods are next squeezed to remove excess acid and prevent the acid from rotting the goods. The goods are next given a lye boiling in three sections to remove any remaining fat and dirt. The first is with soda ash ( 1% ), the second with 3.6 % soda, 0.8% caustic and 1.6% rosin. The third is with soda ash alone. The goods are washed with water and ready to bleach.

While still wet the cloth is passed thru a cold bleaching powder bath (  $\frac{1}{2}^{\circ}$  to  $2^{\circ}$  Tw). The cloth is then piled up and allowed to stand for a few hours in which time the hypochlorous acid is set free. It is then treated with a dilute HCl bath to liberate chlorine from the bleach in the fibres. Then it is washed, treated with an antichlor, washed, and dried by steam heating. It is then ready to be dyed.

In extracting the cotton-seed oil in the other part of the cotton industry, the hulls of the seeds are removed. Then the seeds are crushed and the resulting meal heated to  $75^{\circ}$  -  $90^{\circ}$  C and pressed out under 3000-4000 lbs per square inch. The yield

passing over a row of Hansen burner flames. This burns away  
lint, floor, and loose hairs that would prevent the printing of  
a sharp design. The goods are then wet and allowed to soak over-  
night to loosen starch material. Milk of lime and water are  
added the next day. When the cloth is delieed. The milk of lime  
water lime soaps with the fatty material and dissolves the other  
materials. It is then washed with water and passed to the "first  
sour". Here it is treated with dilute  $H_2SO_4$  to remove iron stains  
and metallic oxides. The goods are next agitated to remove excess  
acid and prevent the acid from rotting the goods. The goods are  
next given a live boiling in three sections to remove any remain-  
ing fat and dirt. The first is with soda ash (1%), the second  
with 3.5% soda, 0.8% caustic and 1.5% resin. The third is with  
soda ash alone. The goods are washed with water and ready to  
bleach.

While still wet the cloth is passed thru a cold  
bleaching powder bath ( $\frac{1}{2}$  to 2%  $NaOCl$ ). The cloth is then piled up  
and allowed to stand for a few hours in which time the pyrochlorous  
acid is set free. It is then treated with a dilute  $HCl$  bath to  
liberate chlorine from the bleach in the fibres. Then it is  
washed, treated with an antichlor, washed, and dried by steam  
heating. It is then ready to be dyed.

In extracting the cotton-seed oil in the other part  
of the cotton industry, the hulls of the seeds are removed. Then  
the seeds are crushed and the resulting meal heated to 75°-90°  
and pressed out under 2000-4000 lbs per square inch. The yield

is about 18%. The crude oil is red or redish brown. The oil is heated and treated with caustic soda to remove any free fatty acid. The resulting soap adsorbs any coloring matter and albumin etc. Of course it is thoroughly agitated while this is done. When finished the agitation is stopped, the soap etc. settles to the bottom, and the oil can be drawn off the top. It can then be heated to 100°C and treated with fuller's earth, leaving a water-white or pale yellow oil. It can then be chilled for some time below 12°C and the solid stearin and palmitin will crystalize out and can be removed. These last are used for making oleomargarine. The remaining oil can be turned to a solid by treating with hydrogen and a proper catalyst.

Thus in a unit on the cotton industry the following points should be considered.

#### I. Uses of cotton and its products

- Ref. a. Slosson "Creative Chemistry"
- b. Encyclopedia Britanica
- c. 15 Census of U. S. Vol 2 Manufactures.

#### II. History of cotton industry.

- Ref. a. Encyclopedia Britanica
- b. Miall "History of British Chemical Industry"(Cellulose)
- c. Slosson "Creative Chemistry"

#### III. Problems of the industry.

- Ref. a. Thorpe "Outlines of Industrial Chemistry"
- b. Lamborn "Cottonseed Products."

is about 18%. The crude oil is red or reddish brown. The oil is heated and treated with caustic soda to remove any free fatty acids. The resulting soap absorbs any coloring matter and albumin etc. Of course it is thoroughly agitated while this is done. When finished the agitation is stopped, the soap etc. settles to the bottom and the oil can be drawn off the top. It can then be heated to 100°C and treated with filter, a centrifuge or a water-white or pale yellow oil. It can then be chilled for some time below 12°C and the solid stearin and palmitin will crystallize out and can be removed. These last are used for making stearine. The remaining oil can be turned to a solid by treating with hydrogen and a proper catalyst.

Thus in a unit on the cotton industry the following points should be considered.

- I. Uses of cotton and its products
  - a. Ref. a. Sisson "Creative Chemistry"
  - b. Encyclopaedia Britannica
  - c. IS Census of U. S. Vol 2 Manufactures.
- II. History of cotton industry.
  - a. Ref. a. Encyclopaedia Britannica
  - b. Hall "History of British Chemical Industry" (Cellulose)
  - c. Sisson "Creative Chemistry"
- III. Problems of the industry.
  - a. Ref. a. Thorpe "Outlines of Industrial Chemistry"
  - b. Lamson "Cottonseed Products."

- c. Trotman " Principles of Bleaching & Finishing Cotton."

#### IV. Industrial procedure.

Ref.a. Thorne " Outlines of Organic Chemistry"

- b. Trotman " Principles of Bleaching & finishing Cotton."

- c. Hubner " Bleaching and Dyeing of Vegetable Fibrous Material"

- d. Andes " Vegetable Fats & Oils"

- e. Lamborn " Cottonseed Products."

- f. "Hydrogenation" J. Soc. Chem. Ind. 1912 pp 1155.

In the laboratory two sets of experiments can be run, the first on washing and bleaching cotton fabric, and the other on obtaining oil from the cotton seeds. In the first some samples of unwashed and unbleached cotton can be obtained and treated in the same manner as described above using beakers etc. in place of vats. Some of the cloth should be improperly treated to show the deleterious effect on the fabric of acids. This cloth when bleached can be used later in the unit on dyeing.

In the second part a quantity of seeds can be obtained from some place where the cotton is ginned. These can be crushed and the hulls removed. The resulting meal can then be squeezed in a vise of some sort so that the oil can trickle down and be collected. Or the oil can be extracted with alcohol and the alcohol evaporated. Then the oil can be washed with caustic soda and treated with fuller's earth. Then it can be chilled in an

c. Trotman "Principles of Bleaching & Finishing Cotton."

IV. Industrial procedure.

Ref. a. "Outline of Organic Chemistry"

d. Trotman "Principles of Bleaching & Finishing Cotton."

e. Hubner "Bleaching and Dyeing of Vegetable Fibrous Material"

f. Andes "Vegetable Fats & Oils"

g. Lashorn "Cottonseed Products."

h. "Hydrogenation" J. Soc. Chem. Ind. 1912 pg 1182.

In the laboratory two sets of experiments can be run.

The first on washing and bleaching cotton fabric, and the other

on obtaining oil from the cotton seeds. In the first some samples

of unwashed and unbleached cotton can be obtained and treated in the

same manner as described above using baskets etc. in place of vats.

Some of the cloth should be improperly treated to show the deleter-

ious effect on the fabric of acids. This cloth when bleached can be

used later in the unit on dyeing.

In the second part a quantity of seeds can be obtained

from some place where the cotton is ginned. These can be crushed

and the hulls removed. The resulting meal can then be suspended

in a vise of some sort so that the oil can trickle down and be

collected. Or the oil can be extracted with alcohol and the al-

cohol evaporated. Then the oil can be washed with caustic soda

and treated with Fuller's earth. Then it can be chilled in an

ice and salt bath and the stearin and polmitin filtered off.

The following materials will be needed.

- |            |  |
|------------|--|
| 1. Beakers | 1. Unbleached cotton fabric  |
| 2. Vise    | 2. NaOH, H <sub>2</sub> SO <sub>4</sub> , CaO, & Na <sub>2</sub> CO <sub>3</sub> |
|            | 3. Bleaching powder & HCl  |
|            | 4. Alcohol   |
|            | 5. Antichlor ( Na <sub>2</sub> S <sub>2</sub> O <sub>3</sub> )                   |
|            | 6. Ice and salt  |

There are no new theoretical points needed here unless one considers the theory of bleaching and use of antichlor. If the oil is extracted by alcohol, the solubility of the oil in alcohol should be explained so that it can be seen why it is possible to extract with alcohol and not water.

1887	281,014,000	"	2,512,000,000	"	219,497,224 lbs.
1898	303,716,000	"	2,326,000,000	"	---
1909	310,261,000	"	2,485,000,000	"	237,204,000 "
1920	306,097,000	"	---	"	---

Wool is one of the animal fibres of which silk is the other big representative. Wool was the material used by the Greeks and Romans to make their clothes with, and hence has been known for a long time. It has had its chief usage in the Northern countries where warm garments are needed, and where sheep can be easily raised. The wool industry of course received a great impetus with the invention of machinery in the textile industry in the last part of the 18th century. Then new places were found where sheep could be easily raised such as South Africa, Argentina, and Australia. Since then the industry has

ice and salt bath and the steam and polymer filtered off.

The following materials will be needed.

- |   |            |
|---|------------|
| 1. Unbleached cotton fabric               | 1. Beakers |
| 2. NaOH, $H_2SO_4$ , $CaO$ , & $Na_2CO_3$ | 2. Vials   |
| 3. Bleaching powder & HCl                 |            |
| 4. Alcohol                                |            |
| 5. Antichlor ( $Na_2SO_3$ )               |            |
| 6. Ice and salt                           |            |

There are no new theoretical points needed here unless

one considers the theory of bleaching and use of antichlor. If the oil is extracted by alcohol, the solubility of the oil in alcohol should be explained so that it can be seen why it is possible to extract with alcohol and not water.

UNIT ON WOOL

Wool is the hair of sheep, certain goats, as well as that of camels. It is used to make fabrics for cloth. It is used extensively in men's clothing, such as socks, suits, shirts, and coats. Women's coats are also made from wool. It is one of the best fabrics made for keeping the body heat in, and the cold air out. Thus it is used to make warm clothing. Its extensive use can be shown by the following figures taken from page 382 of the World Almanac and the 15th Census of the U. S. Vol. 2 Manufactures:

<u>Year</u>	<u>U. S. Production</u>	<u>World Production</u>	<u>Woven in U. S.</u>
1925	253,907,000 lbs.	3,275,000,000 lbs.	- - - -
1926	260,976,000 "	3,468,000,000 "	- - - -
1927	281,914,000 "	3,513,000,000 "	319,657,294 lbs.
1928	303,715,000 "	3,686,000,000 "	- - - -
1929	310,561,000 "	3,608,000,000 "	336,364,964 "
1930	336,007,000 "	- - - - -	- - - -

Wool is one of the animal fibres of which silk is the other big representative. Wool was the material used by the Greeks and Romans to make their clothes with, and hence has been known for a long time. It has had its chief usage in the Northern countries where warm garments are needed, and where sheep can be easily raised. The wool industry of course received a great impetus with the incoming of machinery in the textile industry in the last part of the 18th century. Then new places were found where sheep could be easily raised such as South Africa, Argentine, and Australia. Since then the industry has

UNIT ON WOOL

Wool is the hair of sheep, certain goats, as well as that of camels. It is used to make fabrics for coats, suits, and dresses. It is used extensively in men's clothing, such as suits, shirts, and coats. Women's coats are also made from wool. It is one of the best fabrics made for keeping the body warm in, and the cold air out. Thus it is used to make warm clothing. Its extensive use can be shown by the following figures taken from page 365 of the World Almanac and the Fact Census of the U. S., Vol. 8 Manual:

Year	U. S. Production	World Production	Woven in U. S.
1938	253,907,000 lbs.	2,475,000,000 lbs.	- - - -
1937	260,278,000 "	2,480,000,000 "	- - - -
1936	281,814,000 "	2,513,000,000 "	312,837,324 lbs.
1935	303,713,000 "	2,582,000,000 "	- - - -
1934	310,361,000 "	2,582,000,000 "	335,384,284 "
1933	328,007,000 "	- - - -	- - - -

Wool is one of the animal fibres of which silk is the other big representative. Wool was the material used by the Greeks and Romans to make their clothes with, and hence has been known for a long time. It has had its chief usage in the world in countries where warm garments are needed, and where sheep can be easily raised. The wool industry of course received a great impetus with the invention of machinery in the textile industry in the last part of the 18th century. Then new places were found where sheep could be easily raised such as South Africa, Argentina, and Australia. Since then the industry has

steadily grown. There was a tremendous boom in the wool industry previous to the World War and during it, so that now it, like the cotton industry, is suffering from over production.

Wool does not have the same composition as cotton which is nearly pure cellulose ( $(C_6H_{10}O_5)_x$ ) but is composed mainly of keratin which occurs in bone, feathers etc. The composition of keratin varies but the following is an approximate analysis;

Carbon	49.25%
Nitrogen	15.86%
Hydrogen	7.57%
Sulphur	3.66%
Oxygen	23.66%

The problems in this industry are the same as in the making of cotton fabric, namely how to wash and bleach the fabric. The answer is not the same but just the opposite. Dilute mineral acids do not harm the wool, but alkalies readily attack it. Therefore the process is quite different with wool.

However, before the wool can be subjected to any manufacturing processes, it must be cleaned, as it contains about 30 - 80% wool grease, suint, and dirt. The grease cannot be removed by alkalies so it is emulsified with soaps. A soft soap is generally used. It is washed in several vats using the counter current principle. When it emerges from the last vat, it is centrifuged and dried on wire netting by hot air. It is then ready to be made into yarn. Potash can be recovered from the

steadily grown. There was a tremendous boom in the wool industry previous to the World War and during it, so that now it, like the cotton industry, is suffering from over production.

Wool does not have the same composition as cotton which is nearly pure cellulose ( $C_{10}H_{16}O_5$ ) but is composed mainly of keratin which occurs in bones, feathers etc. The composition of keratin varies but the following is an approximate

analysis:

Carbon	48.25%
Nitrogen	12.68%
Hydrogen	7.37%
Sulphur	2.68%
Oxygen	22.62%

The problems in this industry are the same as in the making of cotton fabric, namely how to wash and bleach the fabric. The answer is not the same but just the opposite.

Little mineral acids do not harm the wool, but alkalies readily attack it. Therefore the process is quite different with wool. However, before the wool can be subjected to any

manufacturing processes, it must be cleaned, as it contains about 30 - 80% wool grease, suint, and dirt. The grease cannot be removed by alkalies so it is emulsified with soap. A soft soap is generally used. It is washed in several vats using the count or current principle. When it emerges from the last vat, it is centrifuged and dried on wire racking by hot air. It is then ready to be made into yarn. Losses can be recovered from the

wash waters by calcining, or a grease that can be used as a lubricant is sometimes recovered. Wool containing much vegetable matter must be carbonized by submerging in aluminum chloride solution, centrifuged, and baked. The HCl liberated attacks and destroys the vegetable matter which falls away when the wool is beaten. Just before making the yarn the wool is treated with a little olive<sup>oil</sup> to make it less brittle. This is removed before bleaching.

Before bleaching, the wool cloth is scoured by passing it as a rope thru soap liquors and then thru squeeze rollers. It is then washed and the process repeated until clean, when it is thoroughly washed.

Chlorine cannot be used to bleach wool as it forms a yellow compound with the wool itself. Sulphur dioxide is the material used. The cloth can be exposed to the fumes until bleached or it may be passed thru a solution of sulphurous acid ( $H_2SO_3$ ), washed and dried. This type of bleaching, however, is not permanent as the yellow color gradually reappears, especially if washed with soap or alkalies. It is supposed that some colorless compound is formed by the  $SO_2$ . Hydrogen peroxide ( $H_2O_2$ ) gives a permanent bleach but is too expensive.

Thus in a unit on Wool we should consider.

I. Production and uses of wool.

Ref. a. World Almanac

b. 15th Census of U.S. Vol 2 Manufactures.

c. Pupil observations for use of fabrics.

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## II. Problem of industry

- Ref. a. Thorpe "Outlines of Industrial Chem."  
b. Hannan "Textile Fibres of Commerce."

## III. Industrial Treatment of Wool

- Ref. a. Thorpe "Outlines of Industrial Chem."  
b. Hannon "Textile Fibres of Commerce."

In the laboratory some raw wool obtained from some wool plant can be washed with a soft soap in beakers. Then it can be carbonized by soaking in  $AlCl_3$ , baked, and beaten. Then some unbleached wool can be obtained from the same source and bleached. The wool can be passed thru several (3-5) beakers of soap solution and washed. Then it can be bleached in a  $H_2SO_3$  bath. This can be made by treating sodium bisulphite with hydrochloric acid. Then it can be washed and dried. This cloth can also be used in the dyeing unit. With one portion of the wool a bleaching powder solution can be used to show why it is not used in the industry.

The following materials would be needed for the experiments.

- |                       |                    |
|-----------------------|--------------------|
| 1. Beakers and flasks | 1. Raw wool        |
| 2. Wringer            | 2. Unbleached wool |
| 3. Drier or heat      | 3. Soft soap       |
| 4. Bunsen burner      | 4. Sulphur         |

There are only two theoretical points to consider. The first is the action of acids and alkalies on wool. The second is the bleaching of wool and why chlorine cannot be used.

II. Treatment of Industry

- 1. Type "Outline of Industrial Wool"
- 2. Type "Outline of Industrial Wool"

III. Industrial Treatment of Wool

- 1. Type "Outline of Industrial Wool"
- 2. Type "Outline of Industrial Wool"

In the laboratory some raw wool obtained from some

wool plant can be washed with a soft soap in benzene. Then it

can be reprecipitated by washing in  $AlCl_3$ , benzene, and benzene. Then

some undegraded wool can be obtained from the same source and

bleached. The wool can be passed from several (3-5) portions of

soap solution and washed. Then it can be bleached in a 5%  $H_2O_2$

solution. This can be made by treating sodium bisulfite with hydrogen

peroxide. Then it can be washed and dried. This wool can

also be used in the dyeing mill. With one portion of the wool

a bleaching solution can be used to show why it is not

used in the industry.

The following materials would be needed for the

experiment.

1. Raw wool	1. Benzene and Hexane
2. Undegraded wool	2. Hydrogen peroxide
3. Soft soap	3. Sodium bisulfite
4. Bleach	4. Dyeing mill

There are only two theoretical points to consider.

The first is the action of acids and alkalis on wool. The

second is the bleaching of wool and why chlorine cannot be used.

## RAYON

In chemistry we have the development of an industry generally in three steps. The first is the utilization of natural products; second, cultivation of natural products; and third, manufacture of artificial products. Rayon is fairly new in this country, beginning about 1910; but <sup>it</sup> has grown to rather large proportions since then. The following figures from page 382 of the World Almanac can best show the growth.

### RAYON

<u>Year</u>	<u>U. S. Production</u>	<u>World Production</u>	<u>World Production-Silk</u>
1911	320,000 lbs.	- - - - -	57,143,000 lbs.
1915	4,111,000 lbs.	- - - - -	53,088,000 lbs.
1920	10,240,000 lbs.	50,000,000 lbs.	46,500,000 lbs.
1925	51,902,000 lbs.	185,000,000 lbs.	88,052,000 lbs.
1926	63,648,000 lbs.	212,300,000 lbs.	97,348,000 lbs.
1927	75,555,000 lbs.	297,340,000 lbs.	102,181,000 lbs.
1928	97,901,000 lbs.	344,550,000 lbs.	108,431,000 lbs.
1929	122,066,000 lbs.	406,018,000 lbs.	100,125,000 lbs.
1930	110,208,000 lbs.	440,000,000 lbs.	99,065,000 lbs.

Thus we see that the United States produces about 25% of the total world production of rayon, and the weight of rayon produced in this country exceeds the total world production of silk. Rayon's chief use is in making mixed goods. It is cheaper than silk and can be used to mix with cotton and wool. It is used alone to make some garments such as hosiery and under clothes. Some is used to make transparent velvet that is used for evening gowns. Its chief use is in mixing with other goods.

As early as 1664 there was an idea that artificial silk might be made that was suggested by Hooke. Again in 1734 it was suggested by Reamur. In 1740 Bon made some suggestions on how it could be made. In 1855 An<sub>n</sub>dermars of Tousanne made the first

RAYON

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RAYON

Year	U. S. Production	World Production	World Production-Silk
1911	320,000 lbs.	- - - - -	57,143,000 lbs.
1915	4,111,000 lbs.	- - - - -	55,088,000 lbs.
1920	10,240,000 lbs.	50,000,000 lbs.	48,200,000 lbs.
1925	51,920,000 lbs.	188,000,000 lbs.	88,082,000 lbs.
1926	63,848,000 lbs.	212,300,000 lbs.	97,248,000 lbs.
1927	75,252,000 lbs.	227,340,000 lbs.	102,181,000 lbs.
1928	97,901,000 lbs.	344,250,000 lbs.	108,431,000 lbs.
1929	122,082,000 lbs.	408,018,000 lbs.	100,122,000 lbs.
1930	110,208,000 lbs.	440,000,000 lbs.	99,082,000 lbs.

Thus we see that the United States produces about 25% of the total world production of rayon, and the weight of rayon produced in this country exceeds the total world production of silk. Rayon's chief use is in making mixed goods. It is cheaper than silk and can be used to mix with cotton and wool. It is used alone to make some garments such as hosiery and underclothes. Some is used to make transparent velvet that is used for evening gowns. Its chief use is in mixing with other goods.

As early as 1854 there was an idea that artificial silk might be made and was suggested by Hooke. Again in 1854 it was suggested by Reaumur. In 1840 Bon made some suggestions on how it could be made. In 1855 A. L. Lavoisier of Toussaint made the first

artificial threads, but they were of no importance commercially. In 1883 the first use was made of these artificial fibres when Swan in England carbonized them and used them as a filament for light bulbs. He also thought they might be used as a fabric and his wife crocheted some small mats and doilies that were exhibited in 1885. In 1884 de Chardonnet forced a solution of nitrocellulose in alcohol and ether thru small openings and got threads. In 1891 he started the first factory that in 1907 was making 2,000 kilogrammes a day. This definitely set up the nitrocellulose method.

In 1892, Cross, Bevan, and Beadle found that if cellulose after being treated with caustic soda, were to be treated with carbon bisulphide, the resulting xanthate was soluble in caustic and water. They also found that on treating with acid the cellulose was regenerated and fibres could be made by regenerating after squirting thru holes into the acid bath. They set up a plant, but not until 1906 was successful large scale production really realized.

In 1857 Schwietzer found (after Mercer) that cellulose was soluble in ammoniacal solution of copper oxide. This result was studied further by Despaissis in 1890, and Pauly, with the idea of making artificial silk. Pauly succeeded and took out a patent in 1897.

The last method is the acetate method for making artificial silk. Patents were taken out in 1894 by Cross and Bevan

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but were not successful commercially. In 1905 A. W. Miles in Boston found the secret of "ripening" cellulose acetate, and the last form of making artificial silk was on its feet.

The Viscose process is used to make the great majority of rayon produced. In 1928 in this country 83.3% of all artificial silk was made by this process. Nitro-cellulose furnished 9%, Acetate, 5%; and cupra-ammonium 2.7%. For this reason we shall confine ourselves to the viscose process, though it would be an excellent idea to let the pupils compare the dyeing and strength of rayon made from all four sources.

In any process the problem for the chemist is to put cellulose in some form into solution and to regenerate it in the form of a fine thread. In the viscose process the problem is solved as follows: The source of cellulose ( wood pulp or cotton linters) is steeped in caustic to dissolve out impurities and to form another type of cellulose. This is shredded and stored to "ripen". This "ripening" is necessary but what takes place is not definitely known. Next this material is treated with carbon bisulphide to form cellulose xanthate, a yellow solid. This last is next mixed with caustic and water to make golden yellow viscous liquid or viscose. This viscose is ripened, but again we do not know why. It is then pumped to the spinning room and forced thru small openings into a bath containing sulphuric acid. This neutralizes the caustic and precipitates the cellulose out as a thread. This thread is collected by either a bobbin or bucket depending on the type of plant. The thread is next washed free

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of acid and dried, as the acid unless removed will attack the yarn. The thread is next "thrown" to put a twist in the yarn. The thread is now wound to skeins. Here again chemistry enters. The yarn contains some traces of carbon bisulphide ( $CS_2$ ) that will attack knitting needles unless removed. This is done by treating with a solution of sodium sulphide solution which dissolves it out. The yarn is washed, bleached, and dried and is ready for market.

There are several other problems that are always claiming the attention of the chemist. One of these is that the spinning bath must have just such a composition or the dye qualities of the yarn are affected. Another is the desulphuring solution if the yarn is run to cones instead of skeins. Here the sulphide bath will attack aluminum bobbins ( in a small bobbin plant ) unless the OH ion is suppressed in some manner such as adding soluble glass and bicarbonate of soda.

Thus in a unit on rayon the following points might be mentioned.

#### I. The production & uses of rayon.

- Ref. a. World Almanac
- b. Holmes " General Chemistry"
- c. Pamphlet on rayon from some rayon company ( DuPont)

#### II. History of growth

- Ref. a. Miall, "History of British Chemical Industry"
- b. Slosson, "Creative Chemistry"

of acid and dried, as the acid unless removed will attack the yarn.  
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Thus in a unit on rayon the following points might be

mentioned.

I. The production & uses of rayon.

Ref. a. World Almanac

b. Holmes "General Chemistry"

c. Pamphlet on rayon from some rayon company  
(Detroit)

II. History of growth

Ref. a. Mall. "History of British Chemical Industry"

b. Storer. "Creative Chemistry"

III. The problem and manufacture of rayon

Ref. a. Cross & Bevan "Cellulose"

b. Shoemaker "Viscose Rayon" J. Chem. Ed.  
Vol. 5, p. 1260

c. Tittle "Chemical Industry" J. Chem. Ed. Vol.  
5, p 648.

In the laboratory it would be well to treat cellulose with the four solvents to show the basis of the four branches of the industry. Cotton or wood pulp can be used as the source of cellulose and can be treated in beakers containing the appropriate solvent. With the viscose solution we can try to spin a fibre. The viscose can be blown out of a flask by air pressure through a nozzle made by drawing out glass tubing and breaking it, leaving a small hole. The nozzle can be placed in a pneumatic trough containing a solution of sulphuric acid. This can be drawn out by running under a glass bar onto a spool that can be rotated by hand or machine. When full, the spool can be washed free of acid and dried. Of course this thread will be far different from the finished thread, but it shows the principle underlying the spinning of viscose rayon. \*

Material needed would be as follows:

- |                            |                                    |
|----------------------------|------------------------------------|
| 1. Beakers                 | 1. Cellulose (cotton or wood pulp) |
| 2. Flasks                  | 2. Caustic & carbon bisulphide     |
| 3. Pneumatic trough(glass) | 3. Ammonia & calcium oxide         |
| 4. Glass & rubber tubing   | 4. Acetic Anhydride                |
| 5. Glass rod               | 5. Nitric Acid & alcohol           |
| 6. Spool                   | 6. Sulphuric Acid                  |

\* Quality of product doubtful. See discussion of laboratory procedure on pages 161-62.

III. The problem and manufacture of rayon  
 Ref. e. Cross & Bevan "Cellulose"  
 D. Shoemaker "Viscose Rayon" J. Chem. Ed.  
 Vol. 5, p. 1260  
 c. Little "Chemical Industry" J. Chem. Ed. Vol.  
 5, p. 848.

In the laboratory it would be well to treat cotton-lose with the four solvents to show the parts of the four branches of the industry. Cotton or wood pulp can be used as the source of cellulose and can be treated in beakers containing the appropriate solvent. With the viscose solution we can try to spin a fibre. The viscose can be blown out of a flask by air pressure through a nozzle made by drawing out glass tubing and breaking it leaving a small hole. The nozzle can be placed in a pneumatic trough containing a solution of sulphuric acid. This can be drawn out by running under a glass bar onto a spool that can be rotated by hand or machine. When full, the spool can be washed free of acid and dried. Of course this thread will be far different from the finished thread, but it shows the principle underlying the spinning of viscose rayon. \*

Material needed would be as follows:

- |                                    |                             |
|------------------------------------|-----------------------------|
| 1. Cellulose (cotton or wood pulp) | 1. Beakers                  |
| 2. Caustic & carbon disulphide     | 2. Flasks                   |
| 3. Ammonia & calcium oxide         | 3. Pneumatic trough (glass) |
| 4. Acetic Anhydride                | 4. Glass & rubber tubing    |
| 5. Nitric Acid & alcohol           | 5. Glass rod                |
| 6. Sulphuric Acid                  | 6. Spool                    |

\* Quality of product doubtful. See discussion of laboratory procedure on pages 181-82.

The following points would also help the pupil to a more complete understanding of the unit: corrosive action of acids and bases, bleaching, colloids, crystallization, filtration, polymerization, solubility, and evaporation.

To furnish us with color the art of dyeing has sprung up. It has kept step somewhat behind the amount of textiles produced until fairly recently. Some idea of the extent of the dyeing industry can be realized by the production of dyes in this country. Since the World War we have produced all our own dyes and now export many. The following figures from page 389 of the World Almanac represent the pounds produced annually in this country.

<u>Year</u>	<u>Dyes</u>	<u>Color Takes</u>
1926	36,346,438	11,414,763
1926	37,976,424	11,794,208
1927	35,167,806	11,601,607
1928	36,633,451	12,177,242
1929	111,421,606	13,244,676
1930	66,480,000	9,563,316

These represent coal tar dyes and are used almost completely in this country. The only dye that they do not surpass is log wood for a black dye for silk.

The dyeing industry is a very old one. Fabrics have been found in Egyptian tombs showing that they knew considerable about the art as they used dyes that must be associated with other substances in order to reveal their coloring power. The chief dyes used were indigo and saffron (blue and red) that grew in India, China, Persia, and Egypt. Dyes were probably brought to Europe

The following points would also help the pupil to  
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## UNIT ON DYEING

We all wear clothing in some form or other. Most of this clothing is not in its natural color. We like to vary the colors of our apparel. If it were not for the art of dyeing, we would be wearing clothes of the same color and it would mean a much less colorful world. To furnish us with color the art of dyeing has sprung up. It has kept step somewhat behind the amount of textiles produced until fairly recently. Some idea of the extent of the dyeing industry can be realized by the production of dyes in this country. Since the World War we have produced all our own dyes and now export many. The following figures from page 359 of the World Almanac represent the pounds produced annually in this country.

<u>Year</u>	<u>Dyes</u>	<u>Color Takes</u>
1925	86,345,438	11,414,753
1926	87,978,624	11,796,203
1927	95,167,905	11,601,507
1928	96,625,451	12,127,242
1929	111,421,505	13,244,676
1930	86,480,000	9,563,318

These represent coal tar dyes and are used almost completely in this country. The only dye that they do not surpass is log wood for a black dye for silk.

The dyeing industry is a very old one. Fabrics have been found in Egyptian tombs showing that they knew considerable about the art as they used dyes that must be associated with other substances in order to reveal their coloring power. The chief dyes used were indigo and madder ( blue and red ) that grew in India, China, Persia, and Egypt. Dyes were probably brought to Europe by

The all wear clothing in some form or other. Most of this clothing is not in its natural color. We like to vary the colors of our apparel. If it were not for the art of dying, we would be wearing clothes of the same color and it would mean a much less colorful world. To furnish us with color the art of dying has sprung up. It has kept step somewhat behind the amount of textiles produced until fairly recently. Some idea of the extent of the dyeing industry can be realized by the production of dyes in this country. Since the World War we have produced all our own dyes and now export many. The following figures from page 388 of the World Almanac represent the pounds produced annually in this country.

<u>Year</u>	<u>Dyes</u>	<u>Color Toners</u>
1935	88,345,458	11,414,783
1934	87,978,524	11,708,307
1933	85,187,908	11,801,307
1932	86,888,481	12,137,348
1931	111,481,808	13,844,878
1930	88,480,000	9,883,318

These represent coal tar dyes and are used almost completely in this country. The only dye that they do not surpass is log wood for a black dye for silk.

The dyeing industry is a very old one. Fabrics have been found in Egypton tombs showing that they knew considerable about the art as they used dyes that must be associated with color. It states in order to possess their coloring power. The chief dyes used were indigo and madder (blue and red) that grew in India, China, Persia, and Egypt. Dyes were probably brought to Europe by

the Phoenicians. Pliny gives a description of dyeing with Tyrian purple. Most of these dyes, particularly the last, were probably expensive; and dyeing was not as extensive as it now is, and was mainly a home industry.

In the thirteenth century Federigo in Italy found that certain lichens could be used as purple dye and gave the industry a push. He received many honors. In 1472 Dyers Co. was founded in London for dyeing purposes. Then America was discovered and it was found that the Inca Indians knew how to dye. They were using cochineal as a red dye and obtained it from insects.

In the 17th century Drebbel found how to get scarlet on wool by using cochineal and tin. This probably was the start of mordant dyeing. From 1700-1825 steps were taken to progress the art and the various dye woods began to be used. In 1845 the zinc-lime vat for cotton came into use. In 1856 the first synthetic dye was made and the start of modern dyeing. Since then the methods and dyes have been perfected.

In dyeing the problem for chemistry is to get a colored material into the fibres of the cloth to impart color to it, and to have the color in there firmly enough so that it will not fade or wash out. There are eight types of dyes, depending on the method in which they are applied.

The first type is the direct dye. The dyes are soluble in water and are adsorbed strongly by all fibres. They tend

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In dyeing the problem for chemistry is to get a colored material into the fibres of the cloth to impart color to it and to have the color in there firmly enough so that it will not fade or wash out. There are eight types of dyes, depending on the method in which they are applied.

The first type is the direct dye. The dyes are soluble in water and are absorbed strongly by all fibres. They come

to "bleed" however, and are affected by acids and alkalies. The dye is made up in a bath with an "assistant" (catalyst) and the goods passed thru it. These dyes are used sometimes for mixed goods so that one fabric dyes and the other will not, or gives different shades of the color on the different fabrics. Thus a piece of goods of silk and cotton if dyed in a soap bath dyes the cotton but not the silk.

The second type is the basic dye. These are colorless bases but on the formation of the salt, the color appears. This type is not adsorbed by fibres except of an acid character such as silk or wool, and some insoluble color compound is probably formed with the fibre. Malachite green and methylene blue belong to this type and are all quite brilliant. Wool can be dyed directly but tends to bleed so they are not used much. With silk it is treated in neutral solution and a little acid added to form the color. With silk a mordant must be used.

The third type of dye is the acid dye. These are dyed on animal fibres in acid baths. The acids are the color material and must be formed from the salts and so are used in an acid bath. The azo colors and phthaleins belong to this type. Eosin is an example. The salt is made up into a solution and boiled. A little acetic acid is gradually added and this sets free the color-acid and is adsorbed by the fibre.

The fourth type is the mordant dye. These substances are not adsorbed by the fibres but are by various weak

to "bleed" however, and are affected by acids and alkalis. The dye is made up in a bath with an "assistant" (catalyst) and the goods passed thru it. These dyes are used sometimes for mixed goods so that one fabric dyes and the other will not, or gives different shades of the color on the different fabrics. Thus a piece of goods of silk and cotton if dyed in a soap bath dyes the cotton but not the silk.

The second type is the basic dye. These are color fast dyes but on the formation of the salt, the color appears. This type is not absorbed by fibres except of an acid character such as silk or wool, and some insoluble color compound is probably formed with the fibre. Methylene blue and methyl orange belong to this type and are all quite brilliant. Wool can be dyed directly but tends to bleed so they are not used much. With silk it is treated in neutral solution and a little acid added to form the color. With silk a mordant must be used.

The third type of dye is the acid dye. These are dyed on animal fibres in acid baths. The acids are the color material and must be formed from the salts and so are used in an acid bath. The two colors and phthalates belong to this type. Eosin is an example. The salt is made up into a solution and boiled. A little acetic acid is gradually added and this sets free the color-acid and is absorbed by the fibre.

The fourth type is the mordant dye. These substances are not absorbed by the fibres but are by various weak

metallic hydroxides probably forming definite salts. The condensation of the dye on the hydrate is called a color-lake. The problem here is to get the metallic hydroxide in the fibre and then dye the cloth. The cloth is impregnated with a soluble salt of the metal (Al, Cr, Fe, & Sn) and then given an alkaline wash which sets the hydrate. Then the cloth is put in the dye bath. Turkey-red and logwood black are mordant dyes for cotton.

The fifth type of dye is the acid-mordant dye. These are used chiefly on wool and to some extent on silk. They are similar to the acid dyes except a mordant of chromium hydroxide etc. is used. The dyes mentioned as acid dyes are acid-mordant dyes for wool.

The sixth type is the sulphide dye. These are generally sulphur dyes. They are insoluble in water but are soluble in an alkaline solution such as one of sodium sulphide. On exposure to oxygen insoluble color compounds are formed. In this type of dye are Kryogene, Thiogene and Thionol. The dye solution is made up in wood or iron vats as the sulphide would act on copper to form oxygen-carrying copper salts. The goods are completely submerged until dyed, and then removed and rapidly run thru a squeeze-roll to remove excess and allow even drying. After that they are given a short exposure to air, and rinsed.

The seventh type is the vat dye. Indigo was for a long time the only one of this type known. They are similar to the sulphide dyes being soluble in alkaline solutions and are

metallic hydroxides properly forming definite salts. The complex

action of the dye on the hydroxide is called a color-lake. The

problem here is to get the metallic hydroxide in the form and then

dye the cloth. The cloth is impregnated with a soluble salt of

the metal (Al, Cr, Fe, & Sn) and then given an alkaline wash which

sets the hydroxide. Then the cloth is put in the dye bath. Further

red and brownish black are mordant dyes for cotton.

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are used chiefly on wool and in some extent on silk. They are

similar to the acid dyes except a mordant or metallic hydroxide

etc. is used. The dyes mentioned as acid dyes are acid-mordant

dyes for wool.

The sixth type is the azo dye. These are generally

synthetic dyes. They are insoluble in water but are soluble in an

alkaline solution such as one of sodium sulphide. On exposure

to oxygen (insoluble color compounds are formed. In this type of

dye are Erythrosin, Chrysoidin and Methylol. The dye solution is made

up in wool or horse-hair as the sulphide would set on copper to

form organo-sulphur compounds. The goods are completely sub-

merged with dye, and then washed and finally run through a series

of to remove excess and after even drying, after that they are

given a slight exposure to air and light.

The seventh type is the vat dye. Indigo was for a

long time the only one of this type known. They are similar to

the sulphide dye being soluble in alkaline solutions and are

reprecipitated on exposure to oxygen. Instead of sulphide in the bath solution we have the zinc-lime vat and the hydrosulphite vat. These dyes must be "aged" to be sure the dye is completely transformed into the insoluble form.

The last type of dye is the ingrain color. Here a cloth must be treated with a dye and then treated with a second solution in order to have the dye appear and be fixed. Among these are aniline black and mineral dyes. For instance, mineral dyes are applied as follows. A cloth is soaked in a soluble salt say of iron, and then treated with a calcium hydroxide solution. The insoluble ferric oxide is formed and dyes the cloth.

This finishes the types of dyes. Most of these have been mentioned as having been applied in vats so that the whole piece of goods was dyed. There is another way of applying dyes. This is printing. Here the plain goods are run over rollers and the design stamped on. It is stamped on by copper rollers that have been etched with nitric acid ( $\text{HNO}_3$ ) to the design desired. The indentations pick up the dye paste, the excess is scraped off of the face and deposited on the cloth. Many colors can thus be applied by having several rollers stamp the same piece of cloth, and each roller can contain a different color. By means of printing many intricate designs can be placed on cloths.

Thus in a unit on dyeing the following points should be covered.

responsible for exposure to oxygen. Instead of white in the  
dark solution we have the zinc-lime and the hydroxide  
these may be "aged" to be completely trans-  
ferred into the insoluble form.

The last type of dye is the organic color. These  
dyes must be treated with a dye and then treated with a second  
solution in order to have the dye appear and be fixed. Some dyes  
are either black and mineral dyes. For instance, mineral dyes  
are applied as follows. A cloth is soaked in a solution and left  
of iron, and then treated with a certain hydroxide solution. The  
insoluble ferric oxide is formed and gives the cloth.

This illustrates the types of dyes. Most of those have  
been mentioned as having been applied in ways so that the  
color of goods was good. There is another way of applying dyes.  
This is printing. Here the plain goods are run over rollers and  
the design stamped on. It is stamped on by copper rollers that  
have been soaked with nitric acid (HNO<sub>3</sub>) in the design desired.  
The indentations left on the dye paste, the color is removed off  
of the face and deposited on the cloth. Any color can thus be  
applied by having several rollers stamp the new place of cloth,  
and each roller can contain a different color. By means of print-  
ing any intricate designs can be placed on cloth.

There is a unit on dyeing the following points should  
be covered.

I. Extensive use of dyes

- Ref. a. Observation of clothes.  
b. World Almanac

II. History of dyeing

- Ref. a. Encyclopedia Britanica  
b. Wells, H. G. - "Outline of History"  
c. Slosson "Creative Chemistry" (Synthetic Dyes)  
d. Miall "History of British Chemical Industry (Manufacture of dyes)"

III. The various types of dyes and how they solve the problem.

- Ref. a. Thorpe "Outlines of Industrial Chemistry"  
b. Knecht, Rawson & Loceventhal "Manual of Dyeing"  
c. Wood "The Chemistry of Dyeing"  
d. Beech "The Dyeing of Cotton Fabrics"  
e. Beech "The Dyeing of Woolen Fabrics"

IV. Printing

- Ref. a. Thorpe "Outlines of Industrial Chemistry"  
b. Sansone "The Printing of Cotton Fabrics"

V. The theory of coloring of dyes

- Ref. a. Thorpe "Outlines of Industrial Chemistry"  
b. Moore. "Outlines of Organic Chemistry".

In the laboratory some of the various types of dyes can be tried out in beakers. They should be tried out under conditions satisfactory for dyeing with that particular type of dye and then again if conditions are not satisfactory. The proper conditions have been briefly outlined in the first part of this

I. Extensive use of dyes

- 1. Conservation of dyes
- 2. Dyeing of dyes

II. History of dyeing

- 1. Historical dyeing
- 2. "Outline of History"
- 3. "Dyeing of Dyes" (Lecture)
- 4. "History of British Chemical Industry (Manufacture of Dyes)"

III. The various types of dyes and how they solve the problem

- 1. "Dyeing of Industrial Chemistry"
- 2. "Dyeing of Natural Materials"
- 3. "The Dyeing of Wool"
- 4. "The Dyeing of Cotton Fabrics"
- 5. "The Dyeing of Woolen Fabrics"

IV. Printing

- 1. "Dyeing of Industrial Chemistry"
- 2. "The Printing of Dyeing Fabrics"

V. The theory of colorfastness

- 1. "Dyeing of Industrial Chemistry"
- 2. "Outline of Organic Chemistry"

In the laboratory some of the various types of dyes

can be tried out in practice. They should be listed out under each

of the various types of dyes and their respective uses.

The proper conditions are not satisfactory. The proper

conditions have been briefly outlined in the text of this

unit. It would be a good experiment to make a small printing machine. Two iron rollers can be etched in some simple design such as a circle or a cross by covering with wax except where the design is to be etched. The two rollers can be erected one above the other with a small vat for the dye paste beneath each roller. Then a board can be placed next to them and the cloth be passed up the board and the rollers stamp the design on the cloth. The two rollers should contain different colored dyes.

Materials needed would be as follows:

- |                            |                                     |
|----------------------------|-------------------------------------|
| 1. Beakers                 | 1. Dyes to illustrate various types |
| 2. 2 iron rolls or rollers | 2. Cotton cloth                     |
| 3. 1 board                 | 3. Wool cloth                       |
| 4. Wax                     |                                     |
| 5. Nitric acid             |                                     |

The theoretical points that need be treated to really understand a unit on dyeing are, how the color is imparted to the cloth which needs some idea of adsorption and solubility of solids, hydrolysis, and salt formation. If interest warrants, some theory might be taken up on why dyes have color and include chromophore and auxochrome groups.

unit. It would be a good experiment to make a small printing machine. Two iron rollers can be etched in some simple design such as a circle or a cross by covering with wax except where the design is to be etched. The two rollers can be erected one above the other with a small vat for the dye paste beneath each roller. Then a board can be placed next to them and the cloth be passed up the board and the rollers stamp the design on the cloth. The two rollers should contain different colored dyes.

Materials needed would be as follows:

- |                                     |                            |
|-------------------------------------|----------------------------|
| 1. Dyes to illustrate various types | 1. Beakers                 |
| 2. Cotton cloth                     | 2. 2 iron rolls or rollers |
| 3. Wool cloth                       | 3. 1 board                 |
|                                     | 4. Wax                     |
|                                     | 5. Nitric acid             |

The theoretical points that need be treated to really understand a unit on dyeing are, how the color is imparted to the cloth which needs some idea of absorption and solubility of solids, hydrolysis, and salt formation. It interests students some theory might be taken up on why dyes have color and include chromophore and auxochrome groups.

## UNIT ON GLASS

A great deal of glass is used throughout the country and is of great importance to us. We use it in windows so that light may come in and yet keep the heat or cold outside. If it were not for windows all factory work would depend on the weather. Houses are lighted by it every day and without glass for lamp chimneys or our many million light bulbs there would be far less studying and reading done. We use glass for bottles to hold liquids. We have learned much of bacteria and stars by the aid of microscopes and telescopes with glass lenses. Photography and motion pictures would be unknown. We would be unable to correct defective eyesight. Thus we see how important glass is to modern life. The following figures show how much glass is consumed in this country. ( Taken from 15th United States Census Vol II - Manufactures )

Type of Glass	1929	1927	1925
Plate	148,742,970 sq.ft.	118,123,960	117,369,400
Window	402,558,961 " "	481,021,350	567,150,590
Obscure Gl.	34,293,632 " "	41,544,699	53,951,313
Wire	42,817,257 " "	29,115,049	32,968,946
Tumbler	23,125,547 doz.	27,280,521	29,678,011
Milk Bottles	2,610,083 Gr.	2,180,575	2,086,360
Bottles	9,445,446 "	---	---
Glass tubing	23,066,504 lbs.	21,519,336	16,859,946

Glass making is a very old art. Glass beads were found in the tombs of the rulers of the first Egyptian Dynasty, roughly 5000 B.C. Glass bottles were discovered in the tombs of the later Pharoahs about 4700 B.C. The Greeks also had glass, but it was all colored and used mostly for ornaments. The Romans made some progress in the art of glass making. The Arabs evidently had clear glass as it is stated that they made progress in physics

A great deal of glass is used throughout the country and is of great importance to us. We use it in windows so that light may come in and yet keep the heat or cold outside. It is used for windows all factory work would depend on the weather. Houses are lighted by it every day and without glass for lamp chimneys or our very kitchen light bulbs there would be no light and reading and teaching. We use glass for bottles to hold liquids. We have learned much of bacteria and stains by the aid of microscopes and telescopes with glass lenses. Photography and motion pictures would be unknown. We would be unable to connect detective agencies. Thus we see how important glass is to modern life. The following figures show how much glass is consumed in this country. (Taken from 1934 United States Census Vol II -

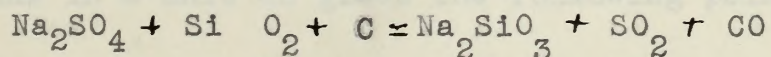
Type of Glass	1929	1934	1938
Plate	148,747,270 sq. ft.	118,102,800	117,350,400
Window	401,858,361 "	481,041,300	507,150,100
Container	34,902,803 "	41,844,800	33,951,513
Pipes	42,817,237 "	29,113,000	32,308,043
Trucks	23,182,547 lbs.	27,300,000	27,878,011
Auto bottles	2,010,000 "	2,100,000	2,082,000
Bottles	2,443,445 "	---	---
Other tubing	20,000,000 lbs.	21,000,000	18,000,000

Glass making is a very old art. Glass bottles were found in the tombs of the pharaohs of the Great Kingdoms. Roughly 5000 B.C. Glass bottles were discovered in the tombs of the later Egyptians about 1500 B.C. The Greeks also had glass, but it was all colored and used mostly for ornaments. The Romans had great progress in the art of glass making. The glass industry had clear glass as it is needed for the windows in houses

along the lines of optics. Galileo (1564-1642) made the first telescope and brought glass to the aid of astronomy. Leeuwenhoek (1632-1723) made the first microscope and brought glass to the aid of biology. Probably no advances have been made in the art of glass making until very recently when certain glasses such as pyrex and jena glasses were made and the development of shatter-proof and bullet proof glass.

Glass is a peculiar substance. It is not a solid but a supercooled liquid. The problem in the glass industry is to procure this supercooled liquid. It is done by fusing together a mixture of silicates. As there are many different silicates in the mixture, the chances of any one crystallizing are very small so the mixture will supercool. Of course, the chemist must see to it that the substances mixed must be pure so that the resulting glass will be colorless, or that it will have the proper amount of dye so as to have the required color.

In brief, this is how glass is made in industry. Sand is the source of silica and must be of a very pure quality. In this country it is obtained in Massachusetts and Pennsylvania. One of the metals used to form the glass is either sodium or potassium and is obtained either as a carbonate or sulphate. If sulphate is used, carbon in some form must be used to reduce the sulphate as follows:

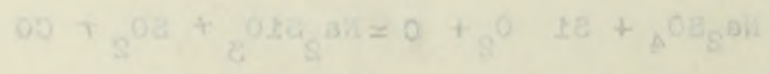


The other metal present to form the mixture is either calcium or lead. The calcium is present as lime stone, or if lead

along the lines of optics. Galileo (1564-1642) made the first telescope and brought glass to the aid of astronomy. Leeuwenhoek (1632-1723) made the first microscope and brought glass to the aid of biology. Probably no advances have been made in the art of glass making until very recently when certain glasses such as Pyrex and Jena glasses were made and the development of shatter-proof and bullet proof glass.

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In brief, this is how glass is made in industry. Sand is the source of silica and must be of a very pure quality. In this country it is obtained in Massachusetts and Pennsylvania. One of the metals used to form the glass is either sodium or potassium and is obtained either as a carbonate or sulphate. If sulphate is used, carbon in some form must be used to reduce the sulphate as follows:



The other metal present to form the mixture is either calcium or lead. The calcium is present as lime stone, or it lead

is used, it is present as litharge ( $PbO$ ) or red lead ( $Pb_3O_4$ ). Some decolorizing agent is used and the commonest one is pyrolusite ( $MnO_2$ ). ( To decolorize it is necessary to oxidize ferrous salts to ferric salts which only leave a pale yellow color).

These materials are placed in a furnace and fused. The flame used in heating must be long, without smoke or soot. For that reason natural gas has been used in this country, and the industry has become centered around Pittsburg. When the glass is properly fused, the glass is ready to be blown. It formerly was blown by men but recently machines have replaced them. The blown cylinder is cut open and allowed to flatten. If bottles are being made they are blown directly by the Owens bottle-blowing machine that can make 10,000 every hour. Plate glass on the other hand is cast and rolled, and after cooling it is ground to remove unevenness.

Pyrex glass is made by adding boron trioxide which reduces the coefficient of expansion and hence reduces its tendency to crack. The shatter-proof glass is made by cementing together sheets of glass with transparent sheets of cellulose-nitrate or cellulose acetate. In this type there are only two layers of glass while in the bullet-proof glass there are five layers.

Thus in a unit on glass the following points should be covered.

#### I. History and present use.

Ref. a. Holmes " General Chemistry"

is used. It is present as a diluent (20%) or as a solvent (75%).  
Some accelerating agent is used and the compound can be prepared  
in the form of a powder. It is necessary to oxidize the  
plate to form a white color which only leaves a pale yellow color.

These white plates are placed in a furnace and fired.  
The time used in heating must be long, without smoke or soot. The  
first reason natural gas has been used in this country, and the in-  
dustry has become centered around it. When the glass is  
properly fired, the glass is ready to be blown. The blown  
glass is not blown but recently technology has replaced them. The blown  
cylinder is not used and allowed to flatten. If bottles are being  
made they are blown directly by the same bottle-blowing machine  
that can make 10,000 every hour. Plate glass on the other hand  
is cast and rolled, and after cooling it is ground to remove im-  
perfections.

Pyrex glass is made by adding boron trioxide which  
reduces the coefficient of expansion and hence reduces the ten-  
dency to crack. The water-proof glass is made by cementing  
together sheets of glass with transparent sheets of cellulose  
acetate or cellulose acetate. In this type there are only two  
layers of glass with in the half-inch glass there are five  
layers.

Thus in a unit on glass the following points should  
be covered.  
I. History and present use.  
II. "General Chemistry"

- b. Thorpe " Outlines of General Chemistry "
- c. H. G. Wells " Outline of History "
- d. Fifteenth Census of U. S. A. Vol 2  
Manufacturers

## II. The Problems in Glass Making and Processes

- Ref. a Thorpe " Outlines of General Chemistry "
- b. Havestadt "Jena Glass"
- c. Curtis " Pyrex" Ind. Eng. Chem. Vol 14  
pp 336.
- d. Morey " Development in Glass Technology"  
Chem. Met. Eng. Vol 34 pp 230.
- e. Partridge " Glass" Ind. Eng. Chem.  
Vol 21 ,pp 177
- f. Sullivan " The Many-Sidedness of Glass"  
Ind. Eng. Chem. Vol 21, pp 638
- g. Biser " Elements of Glass in Glass  
Making".

In the laboratory a mixture could be made up and fused to make a crude glass. Sand, limestone, soda, and pyrolusite could be mixed to form a glass having a rough formula of  $\text{Na}_2\text{O}$ ,  $\text{CaO}$ ,  $6 \text{SiO}_2$ , using only a trace of pyrolusite or it may be entirely omitted. A second batch could be made using sodium sulphate instead of soda . In the second batch bone black or some form of carbon should be used to reduce the sulphate. The two batches should be fused in an agate crucible under a hood. It should be allowed to fuse for a little while and then to cool until pasty. Then some of this could be blown to make glass bulbs. This is about all that can be easily done in an experiment on glass making. The pupils should compare ordinary glass with pyrex or jena for resistance to heat, and, for cracking,

6. "Outline of General Chemistry" by George  
 5. "Outline of History" by H. G. Wells  
 4. "Pittsburgh Census of U. S. A. Vol 2 Manufacturers"

II. The Problem in Glass Making and Processes

6. "Outline of General Chemistry" by George  
 5. "Glass" by H. G. Wells  
 4. "Glass" by H. G. Wells  
 3. "Glass" by H. G. Wells  
 2. "Glass" by H. G. Wells  
 1. "Glass" by H. G. Wells

In the laboratory a mixture could be made up and used

to make a crude glass. Such, limestone, soda, and potash

could be mixed to form a glass having a rough formula of

$\text{Na}_2\text{O} \cdot \text{CaO} \cdot 2\text{SiO}_2$ , using only a trace of potash or if it may be

entirely omitted. A second batch could be made using sodium sil-

icate. In the second batch some black or grey

form of carbon should be used to reduce the sulphur. The two

batches should be fused in an open crucible under a hood. It

should be allowed to fuse for a little while and then to cool

until easy. From now on this could be blown to make glass

bulbs. This is about all that can be easily done in an experi-

ment on glass making. The pupils should compare ordinary glass

with glass of high resistance as that used for insulators.

ordinary glass should be compared with some sample of shatter-proof glass.

Materials needed would be as follows:

- |                                  |                        |
|----------------------------------|------------------------|
| 1. Agate crucible                | 1. Sand                |
| 2. Burners                       | 2. Limestone           |
| 3. Hollow iron tube for blowing. | 3. Soda                |
|                                  | 4. Sodium sulphate     |
|                                  | 5. Boneblack           |
|                                  | 6. Pyrex or Jena glass |
|                                  | 7. Shatter-proof glass |

The following theoretical points would aid one to understand the glass industry, and its problems; oxidation reduction, coefficient of expansion, super-cooled liquids, and some ideas on heterogeneous equilibrium if the reactions are studied.

39,013,264	61,189,483	67,751,706
30,458,881	30,688,038	40,884,758
33,349,520	22,750,283	15,885,401
8,178,938	8,389,271	7,888,942

All figures are represented in pounds and are taken from the Mineral Census of Manufactures - 1925.

In the pioneer days and probably for a long time previous to this soap was made by treating fat with potash (KCO3) leached from wood ashes. This method was satisfactory in early days when wood was plentiful, but think of the demand for wood if this method was still necessary to supply the amount of soap we use today. Still there were plants using this method in England and other countries. In the first quarter of the nineteenth century there occurred two events that started the modern soap industry. The first was that the French chemist

ordinary glass should be compared with some sample of shatter-  
proof glass.

Materials needed would be as follows:

- |                        |                   |
|------------------------|-------------------|
| 1. Sand                | 1. Agate crucible |
| 2. Limestone           | 2. Burners        |
| 3. Soda                | 3. Hollow iron    |
| 4. Sodium sulphate     | tube for blowing. |
| 5. Borax               |                   |
| 6. Pyrex or lens glass |                   |
| 7. Shatter-proof glass |                   |

The following theoretical points would aid one to

understand the glass industry, and its problems; oxidation  
reduction, coefficient of expansion, super-cooled liquids, and  
some ideas on heterogeneous equilibrium if the reactions are  
studied.

## UNIT ON SOAP

We all know that dirt carries bacteria. It is hard to remove dirt completely by just warm water. Sand may help if near at hand, but it is very rough. Some material is needed to help us keep clean and that material is soap. Personal cleanliness is a great aid in combating many diseases and since that fact has been recognized, soap has played a great part in healthiness. Perhaps a few figures may help to show how great a place the soap industry has in this country.

<u>Type of Soap</u>	<u>1927</u>	<u>1925</u>	<u>1923</u>
Hard Soap	2,219,228,479	2,109,133,309	2,000,340,573
Powder "	173,930,283	142,321,736	
Soap Powders	526,452,627	547,986,130	655,060,628
Liquid Soap	24,933,523	22,047,417	17,879,054
Soft "	59,013,964	61,189,483	67,751,705
Paste "	30,458,681	30,086,038	40,584,255
Special "	33,249,520	22,750,253	15,685,401
Soap Bases	8,178,932	5,382,271	7,553,942

All figures are represented in pounds and are taken from the Biennial Census of Manufacture - 1928.

In the pioneer days and probably for a long time previous to this soap was made by treating fat with potash (K<sub>2</sub>CO<sub>3</sub>) leached from wood ashes. This method was satisfactory for early days when wood was plentiful, but think of the demand for wood if this method was still necessary to supply the amount of soap we use today. Still there were plants using this method in England and other countries. In the first quarter of the nineteenth century there occurred two events that started the modern soap industry. The first was that the French chemist

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Type of Soap	1927	1925	1923
Hard Soap	2,219,228,473	2,109,133,309	2,000,340,873
" Powder	173,930,283	142,321,736	623,060,328
Soap Powders	226,452,627	247,286,130	17,879,024
Liquid Soap	24,323,223	22,047,417	27,731,705
" Soft	29,013,384	21,129,483	40,584,225
" Paste	30,428,881	30,082,038	12,622,401
Special "	23,249,220	22,720,223	7,222,242
Soap Bases	2,178,922	2,222,271	

All figures are represented in pounds and are taken from the Statistical Census of Manufacture - 1928.

In the pioneer days and probably for a long time previous to this soap was made by treating fat with potash (K2CO3) leached from wood ashes. This method was satisfactory for early days when wood was plentiful, but think of the demand for wood if this method was still necessary to supply the amount of soap we use today. Still there were plants using this method in England and other countries. In the first quarter of the nineteenth century there occurred two events that started the modern soap industry. The first was that the French chemist

Chevreul (1786-1889) after several years of investigation showed the proper explanation of the formation of soap as being due to the hydrolysis of fats by caustic potash. He found that caustic soda was just as effective and gave a hard soap instead of a soft one. But the source of caustic soda was just as scarce. However, as will be mentioned later, Leblanc in 1790 had found a cheap commercial way to manufacture caustic. It was not very long until plants sprang up using soda instead of potash for the manufacture of soap. In 1801 the first plant of this type was erected in England.

Since this time there has been no change in the fundamental principles, but much has occurred in the refinement of the process. The oils and fats are now selected very carefully instead of haphazardly in order to prepare a soap that is uniform. The maker buys carefully many natural or synthetic perfumes to give his compounds a distinctive aroma. Much progress has been made in the extraction of the oils. Another event that influenced the soap maker was the discovery in 1846 of nitroglycerine and in 1888 and '91 of cordite and ballistite that are used as explosives. Their base is glycerine, and glycerine is a by-product of the soap plant. Until 1885 all the glycerine was thrown away, but since then it has been recovered and refined for further use by the soap plants.

The problem for the chemist in the soap plant is to supervise the hydrolysis of fats by caustic (soda or potash) and to separate the resulting ester in its pure form. This ester is the soap. A second problem of no less importance is

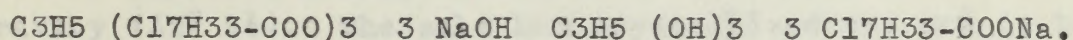
Chevreul (1786-1889) after several years of investigation showed the proper explanation of the formation of soap as being due to the hydrolysis of fats by caustic potash. He found that caustic soda was just as effective and gave a hard soap instead of a soft one. But the source of caustic soda was just as scarce. However, as will be mentioned later, Leblanc in 1790 had found a cheap commercial way to manufacture caustic. It was not very long until plants sprang up using soda instead of potash for the manufacture of soap. In 1801 the first plant of this type was erected in England. Since this time there has been no change in the fundamental principles, but much has occurred in the refinement of the process. The oils and fats are now selected very carefully instead of haphazardly in order to prepare a soap that is uniform. The maker buys carefully many natural or synthetic perfumes to give his compounds a distinctive aroma. Much progress has been made in the extraction of the oils. Another event that influenced the soap maker was the discovery in 1846 of stearic acid and in 1858 and '61 of cordite and palmitic acid that are used as exfoliants. Their base is glycerine, and glycerine is a by-product of the soap plant. Until 1883 all the glycerine was thrown away, but since then it has been recovered and refined for further use by the soap plants.

The problem for the chemist in the soap plant is to supervise the hydrolysis of fats by caustic (soda or potash) and to separate the resulting ester in its pure form. This ester is the soap. A second problem of no less importance is

the selection of oils to be hydrolysed. These oils must be uniform so as to obtain a uniform product. The third is the recovery and purification of the by-product glycerine.

Perhaps it would be best to consider the second problem first as it is here our industry starts. For the best grade soap, the best grades of tallow, tallow oil, palm oil, or cocoanut oil are used. Cottonseed or corn oil very easily become rancid causing a mottled appearance in the soap and a bad odor. (In Europe olive oil is used for Castile soap.) For laundry and other <sup>uses</sup> cheaper soaps are made from tallow, bone grease, house grease, and cottonseed oils. Toilet soaps are made from the best material, although certain cheap kinds are made from poorer stock than laundry soap and the defects covered by high color and scent.

In the actual manufacture, or our first problem, the fat or oil is melted and run into the kettles. The amount of caustic necessary to complete the reaction is run in and can be calculated from the following equation if the type of fat is known.



With "boiled" soaps the mixture is stirred and heated. With some fats such as cocoanut oil the heat of saponification is enough to keep the reaction going. When saponification is complete, the soap is "salted out" by adding salt. This causes the soap to rise and the glycerine, lye, and salt collect on the bottom. This bottom layer is drawn off. More strong lye

the selection of oils to be hydrolyzed. These oils must be uniform so as to obtain a uniform product. The third is the recovery and purification of the by-product glycerine. Perhaps it would be best to consider the second problem first as it is here our industry starts. For the best grade soap, the best grades of tallow, tallow oil, palm oil, or coconut oil are used. Cottonseed or corn oil very easily become rancid causing a mottled appearance in the soap and a bad odor. (In Europe olive oil is used for Castile soap.) For laundry and other <sup>uses</sup> cheaper soaps are made from tallow, bone grease, house grease, and cottonseed oils. Toilet soaps are made from the best material, although certain cheap kinds are made from poorer stock than laundry soap and the defects covered by high color and scent. In the actual manufacture, on our first problem, the fat or oil is melted and run into the kettles. The amount of caustic necessary to complete the reaction is run in and can be calculated from the following equation if the type of fat is known.

$$\text{C}_3\text{H}_5(\text{C}_17\text{H}_33\text{COO})_3 + 3\text{NaOH} \rightarrow \text{C}_3\text{H}_5(\text{C}_17\text{H}_33\text{COO})_3 + 3\text{C}_17\text{H}_33\text{COONa}$$

With "boiled" soaps the mixture is stirred and heated. With some fats such as coconut oil the heat of saponification is enough to keep the reaction going. When saponification is complete, the soap is "salted out" by adding salt. This causes the soap to rise and the glycerine, lye, and salt collect on the bottom. This bottom layer is drawn off. More strong lye

is added, and with white soaps, more cocoanut oil or tallow, and the mass boiled for two or three days. It is then allowed to stand and the lye drawn off. It is then treated with water and allowed to stand for several days. The soap is liquid (from heat) and is on top with the lye at the bottom and a layer of "nigre" (soap, lye, glycerine, etc.) in between. The lye and nigre are drawn off and the soap run to crutchers where it is thoroughly stirred and scent and filling materials added. It is then run to forms and allowed to solidify. The rest of the process is mechanical (cutting it up to bars, flakes, and powder).

The third problem in the soap industry is the recovery of our glycerine from the lye solution and is done as follows: The spent lye is treated with "persulphate of iron", (probably a mixture of ferric and ferrous sulphate in sulphuric acid). This treatment precipitates out any soap and lye. The excess acid is neutralized with caustic and the liquid filtered to remove the sludge formed. It is next run to vacuum evaporators and concentrated. It is run to a certain specific gravity (32° Bè). The salt has crystallized out and is taken out the bottom. The liquid is now distilled under high vacuum (28-29 in.). The glycerine condenses out mainly in the first condenser and is collected, filtered, and sold as "dynamite glycerine."

Thus in a unit on soap it might be well to touch the following points:

is added, and with white soap, more coconut oil or tallow, and the mass boiled for two or three days. It is then allowed to stand and the lye drawn off. It is then treated with water and allowed to stand for several days. The soap is liquid (from heat) and is on top with the lye at the bottom and a layer of "nigre" (soap, lye, glycerine, etc.) in between. The lye and nigre are drawn off and the soap run to crushers where it is thoroughly stirred and scented and filling materials added. It is then run to forms and allowed to solidify. The rest of the process is mechanical (cutting it up to bars, flakes and powder).

The third problem in the soap industry is the recovery of our glycerine from the lye solution and is done as follows: The spent lye is treated with "peroxyphate of iron", (probably a mixture of ferric and ferrous sulphate in sulphuric acid). This treatment precipitates out any soap and lye. The excess acid is neutralized with caustic and the liquid filtered to remove the sludge formed. It is next run to vacuum evapo-

ators and concentrated. It is run to a certain specific gravity (32° Bé.). The salt has crystallized out and is taken out the bottom. The liquid is now distilled under high vacuum (28-30 in.). The glycerine condenses out mainly in the first condenser and is collected, filtered, and sold as "dynamic glycerine."

Thus in a unit on soap it might be well to touch the following points:

- I. Importance and consumption of soap  
Ref. a) Holmes "General Chemistry"  
b) Biennial Census of Manufacturers
- II. History of the industry.  
Ref. a) Holmes "General Chemistry"  
b) Thorpe "Outlines of Industrial Chemistry"  
c) Watts "Manufacture of Hard and Soft Soaps"
- III. Problems and processes of the soap industry
  - a) Thorpe "Outlines of Industrial Chemistry"
  - b) "The Twitchell Process" Ind. Eng. Chem. Vol. 9  
Page 192.
  - c) Watts "Manufacture of Hard and Soft Soaps"
  - d) Lamborn "American Soaps, Candles & Glycerine"
  - e) Gathman "American Soaps"

In the laboratory it will be quite easy to perform one or two experiments to illustrate this industry. Palm or cocoanut oil can be obtained and used as our oil. It would be well to run two batches, one using caustic potash (KOH) and one caustic soda (NaOH). The oil can be heated and the caustic solution added. If some child can get some tallow, a third and fourth might be run by melting the tallow and treating it with both KOH and NaOH. Care should be taken to prevent too much heating of the solution as saponification gives off heat. When finished common salt can be added to salt out the soap and allowed to stand and then remove the soap on top and treat again with caustic if pure soap is desired. The lye solution should be saved. After a second boiling with caustic, the soap can be washed and separated. The soap from the four sources should be compared --- to see the importance of the oils and fats used and whether potash or soda is used.

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 d) Lamson "American Soaps, Candles & Glycerine"  
 e) Gathman "American Soaps"

In the laboratory it will be quite easy to perform one or two experiments to illustrate this industry. Palm or coconut oil can be obtained and used as our oil. It would be well to run two batches, one using caustic potash (KOH) and one caustic soda (NaOH). The oil can be heated and the caustic solution added. If some chile can get some tallow a third and fourth might be run by melting the tallow and treating it with both KOH and NaOH. Care should be taken to prevent too much heating of the solution as saponification gives off heat. When finished common salt can be added to salt out the soap and allowed to stand and then remove the soap on top and treat again with caustic if pure soap is desired. The lye solution should be saved. After a second boiling with caustic, the soap can be washed and separated. The soap from the four sources should be compared --- to see the importance of the oils and fats used and whether potash or soda is used.

The lye solution can have ferric sulphate and  $H_2SO_4$  added until neutral. This can be filtered and evaporated until the salt crystallizes out. The liquid can be decanted and put in a distilling apparatus with a fractionating column and run under vacuum until the water is removed. This would leave a crude "dynamite" glycerine. A still cruder glycerine would be left if the fractionating column was not used. Care should be taken to prevent direct flame touching the distillation flask.

Materials needed would be as follows:

- |                            |                    |
|----------------------------|--------------------|
| a) Several 2-liter beakers | a) Cottonseed oil  |
| b) Bunsen burners          | b) Tallow          |
| c) Separatory funnels      | c) Caustic potash  |
| d) Filter funnel           | d) Caustic soda    |
| e) Distilling flask        | e) Salt            |
| f) Ejector (for vacuum)    | f) $H_2SO_4$       |
| g) Fractionating column    | g) Ferric sulphate |

If it is possible to obtain wood ashes, it would be well to run a fifth experiment by obtaining the caustic potash from leaching the wood ashes with water as our ancestors did in pioneer days.

The following theoretical points would help to understand the unit: -- effect of temperature on reaction, evaporation (vacuum), saponification and hydrolysis, emulsions, and solubility of solids.

The lye solution can have ferric sulphate and H2SO4 added until neutral. This can be filtered and evaporated until the salt crystallizes out. The liquid can be decanted and put in a distilling apparatus with a fractionating column and run under vacuum until the water is removed. This would leave a crude "dynamicite" glycerine. A still crude glycerine would be left if the fractionating column was not used. Care should be taken to prevent direct flame touching the distillation flask.

Materials needed would be as follows:

- |                    |                            |
|--------------------|----------------------------|
| a) Cottonseed oil  | a) Several 2-liter beakers |
| b) Tallow          | b) Bunsen burners          |
| c) Caustic potash  | c) Separator funnels       |
| d) Caustic soda    | d) Filter funnel           |
| e) Salt            | e) Distilling flask        |
| f) H2SO4           | f) Ejector (for vacuum)    |
| g) Ferric sulphate | g) Fractionating column    |

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The following theoretical points would help to understand the unit: -- effect of temperature on reaction, evaporation (vacuum), saponification and hydrolysis, emulsions, and solubility of solids.

## UNIT ON SUGAR

Sugar is the first and greatest contribution of chemistry to the world's diet. It is a single compound, sucrose, with the formula  $C_{12}H_{22}O_{11}$ . Except for fats there is no food, pound for pound, that gives more nutrition, but it is incapable of sustaining life alone. It is the quickest and one of the cheapest means of supplying bodily energy. A few figures may perhaps best show its importance as a food. These figures show the production of sugar in thousands of pounds and the average consumption per capita for the United States in pounds.

<u>Year</u>	<u>U. S. Production</u>		<u>World</u>	<u>Consumption per capita United States</u>
	<u>Beet</u>	<u>Cane</u>	<u>Total</u>	
1928	2,122,000 lbs.	264,106	30,672,000 tons	119.0
1929	2,036,000 "	399,218	30,521,000 "	104.0
1930	2,370,000 "	367,386	31,505,000 "	

Assuming an average consumption of 110 pounds per capita, the United States consumed 13,505,255,000 pounds in 1930-1. This represents a consumption of 42.9% of the worlds total production.

Sugar is not a synthetic product, so the business of the chemist has been to extract it from its source and purify it. The chief commercial sources are either the sugar cane or the sugar beet. The sugar cane was first grown in the East Indies and knowledge of it come to Europe by story. Eventually small supplies of sugar began to be brought to Europe by traders. The Arabs brought the cane plant to Spain; and the Spaniards brought it to the West Indies, where it

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Year	U. S. Production		World Total	Consumption per capita United States
	Beet	Cane		
1928	2,122,000 lbs.	264,106	30,842,000 tons	110.0
1929	2,038,000 "	332,212	30,521,000 "	104.0
1930	2,270,000 "	357,388	31,502,000 "	

Assuming an average consumption of 110 pounds per capita, the United States consumed 13,508,255,000 pounds in 1930-1. This represents a consumption of 42.9% of the world's total production.

Sugar is not a synthetic product, so the business of the chemist has been to extract it from its source and purify it. The chief commercial sources are either the sugar cane or the sugar beet. The sugar cane was first grown in the East Indies and knowledge of it came to Europe by story. Eventually small supplies of sugar began to be brought to Europe by traders. The Arabs brought the cane plant to Spain; and the Spaniards brought it to the West Indies, where it

flourished, and soon they became rivals of the East Indies as a source of sugar. The cane requires a warm moist climate with intervals of hot dry weather and so the Indies, East and West, have remained the chief sources of sugar cane.

When England became the mistress of the seas, France and Germany were somewhat cut off from the sources of sugar and began to look for other sources. Marggraf in 1747 discovered that it was possible to extract sugar from beets. In 1801 under the patronage of the King of Prussia a factory to make sugar from beets was set up but failed. In 1810 Napoleon offered one million francs for a successful process utilizing beets, and every one ridiculed him. However, the industry slowly grew and by special selection and treatment the percent of sugar in beets rose from 8% to 18%, and in 1913 the sugar from beets equalled that from cane both in quality and quantity. The beets require a temperate climate and are raised extensively in central Europe and somewhat in this country.

It does not seem as if much chemistry is needed in the separation and purification of sugar. However, the problem for the chemist is not the control of reactions but the prevention of reactions that might take place. Our sugar or sucrose is but one of many sugars. Among these are glucose (grape sugar), lactose (milk sugar), fructose (fruit sugar), levulose (in honey), and maltose (malt sugar). Sugar tends to

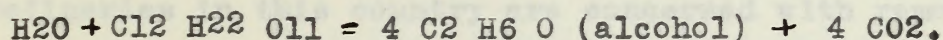
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It does not seem as if much chemistry is needed in the separation and purification of sugar. However, the proper use of the chemical is not the subject of reactions but the prevention of reactions that might take place. Our sugar or sucrose is not one of many esters. It is a dihydroxy ketone (sugar acid), lactone (sugar acid), lactone (fruit sugar), lactone (in honey), and maltose; and sugar tends to

invert when in water solution, and the chemist tries to stop this. This means that one molecule of sucrose ( $C_{12}H_{22}O_{11}$ ) plus one molecule of water ( $H_2O$ ) tend to make two molecules of monosacharides, one being glucose and the other fructose.

Another reaction that can occur after hydrolysis if given a chance is the fermentation of sugar to form alcohol and carbon dioxide. This is the basis of the alcoholic beverage industry and can be represented as follows.



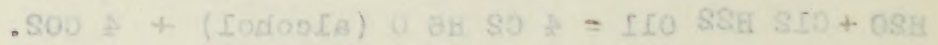
Glucose is a sugar but will not crystallize from water solution. The production of alcohol is producing a product that is not wanted in this industry and represents a loss of material.

As all refineries in this district use crude cane sugar, we will only mention the operations of production from cane sugar and omit the beet sugar refining.

There is about 18% sucrose in the actual sugar cane and a like amount in the ripe cane juice. The used cane is used as fuel to give heat for later processes. Bits of broken cane are removed by screening. Next the syrup is steam heated and milk of lime added. This almost neutralizes organic acids and precipitates them out which tends to stop fermentation. It also coagulates albumin and causes it to rise as a scum. The scum is drawn off to be treated to get sugar out of it,

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It also coagulates albumin and causes it to rise as a scum.

The scum is drawn off to be treated to get sugar out of it.

and the main body has more lime and sawdust added and is then filtered giving a clear liquid. This is evaporated until the sucrose begins to crystallize and reach a grain of a certain size. It is then cooled and the syrup centrifuged off. This gives us our crude sugar with about 95% to 97% sucrose which is sent to the refineries in this country in that state.

Our granulated sugar is 99.8% sucrose, and the refineries in this country are concerned with removing the last 3 or 4% of impurity. Briefly this is how it is done. The sugar is washed with syrup which removes some of the colored impurities, and the excess is centrifuged off. The sugar is next melted with water and lime, and other materials such as Fuller's Earth are added to help defecate it, and the whole mass heated and blown up with air. The mass is then filtered and gives a straw colored solution. It is then run to charcoal filters where the charcoal absorbs the last coloring material. This gives a clear white solution which is evaporated under vacuum until ready to crystallize. This last step is then taken in pans and gives us our white sugar.

The testing of sugars to record whether inversion has set in is an interesting problem. For instance glucose and fructose both have the same formula  $C_6H_{12}O_6$ , yet they are different. Sugar percentages are determined by the rotation of the plane of polarized light as determined by a polariscope. Glucose rotates it to the right and fructose to the left.

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This brings in the problem of isomerism.

Some inversion occurs even at best, and we get syrups that will not crystallize, and some syrup that will not become pure white on filtering. These may be sold as syrup or evaporated and impure sugars made. The best examples are brown sugar, barrel sugar, or, even poorer, we have molasses. Maple sugar is mostly sucrose but is not purified.

Thus the following points should be covered in a unit on sugar.

1. Consumption.

- Ref. a) Slosson "Creative Chemistry." Rev.  
b) "Sugar and Its Value as a Food" by M. N. Abel. Farmers' Bulletin No. 535, Dept. of Agriculture.  
c) Elliott P. "Production of Sugar in the United States and Foreign Countries" (Dept. of Agriculture).

2. History of production and use.

- Ref. a) Slosson "Creative Chemistry" Rev.  
b) Guring "The Worlds' Cane Sugar Industry, Past and Present."  
c) Surface GT "The Story of Sugar"

3. Why sugar purification needs chemical control.

- Ref. a) Slosson "Creative Chemistry" Rev.  
b) Moores "Outlines of Organic Chemistry"  
c) Thorpe "Outlines of Industrial Chemistry"

4. Brief description of process.

- Ref. a) Thorpes "Outlines of Industrial Chemistry"  
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#### 3. Why sugar purification needs chemical control.

- Ref. a) Slosson "Creative Chemistry" Rev.
- b) Moore "Outlines of Organic Chemistry"
- c) Thorpe "Outlines of Industrial Chemistry"

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- Ref. a) Thorpe "Outlines of Industrial Chemistry"
- b) Surface "The Story of Sugar"
- c) Deane "Cane Sugar."

5. (Isomerism)

Ref. a) Moore "Outlines of Organic Chemistry"

In the laboratory it would be fairly simple to take 2 or 3 pounds of crude sugar and purify it. The crude sugar could be easily obtained by writing to some sugar refinery. The process followed to purify this sugar is outlined here. The syrup wash could be obtained by placing the sugar in a tube and allowing the sugar to trickle through and drying by means of a hand centrifuge. The instructor can have the pupils figure how much lime is necessary to neutralize organic acids present, or he may tell them. Fuller's Earth or any similar substance should be added and the mass heated in a steam bath and blown up with air. The syrup can be filtered by ordinary filtration. The char filter can be made by packing animal charcoal in a tube and allowing the syrup to trickle thru. The first portion thru will probably have to be refiltered. A vacuum distillation apparatus is easily set up by means of a flask attached to an ejector, and when the proper place is reached it (the syrup) can be placed in pans and allowed to crystallize. Thus all that would be needed in equipment is:-

- |    |  |    |                                 |
|----|--|----|---------------------------------|
| 1. | 2 fairly long tubes.                               | 1. | 2 or 3 pounds of crude sugar.   |
| 2. | 2 - 2 litre flasks.                                | 2. | Syrup from this sugar for wash. |
| 3. | 1 ejector  | 3. | Milk of lime.                   |
| 4. | 1 steam bath (or water bath can be made by pupils) | 4. | Fuller's Earth                  |
| 5. | Filtration funnel.                                 | 5. | Filter Paper                    |
| 6. | Glass tubing and rubber tubing.                    | 6. | Live animal charcoal            |
| 7. | Bunsen burner.                                     |    |                                 |

Ref. a) Moore's Organic Chemistry

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or to try this. Filter's worth or any similar substance should be

added and the mass heated in a steam bath and blown up with air.

The syrup can be filtered by ordinary filtration. The clear

filtrate can be made by seeking animal charcoal in a tube and

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is equipment as:-

- 1. 2 fairly long tubes.
- 2. 2 - 2 liter flasks.
- 3. 1 ejector.
- 4. 1 steam bath for water.
- 5. 1 glass jar for water.
- 6. 1 liter flask.
- 7. 1 liter flask.
- 8. 1 liter flask.
- 9. 1 liter flask.
- 10. 1 liter flask.
- 11. 1 liter flask.
- 12. 1 liter flask.
- 13. 1 liter flask.
- 14. 1 liter flask.
- 15. 1 liter flask.
- 16. 1 liter flask.
- 17. 1 liter flask.
- 18. 1 liter flask.
- 19. 1 liter flask.
- 20. 1 liter flask.

Besides this experiment in purification we should have two experiments to show the reactions that may take place. The first would be inversion. Some sugar (crude) can be dissolved in water and a little hydrochloric acid added. This hastens the reaction and shows it quickly. A polariscope can detect the difference in the rotation of polarized light, or inversion can be shown by trying to crystallize sugar from the resulting solution.

For the fermentation a little yeast is necessary. The carbon dioxide can be detected by means of  $Ba(OH)_2$  or  $Ca(OH)_2$  and the alcohol by the odor.

For these experiments we will need:-

1. 2 - 1 litre beakers.
2. 1 - Polariscope.
3. HCl.
4. Yeast.
5.  $Ba(OH)_2$  or  $Ca(OH)_2$ .

The following theoretical knowledge will aid in understanding the subject of sugar, absorption, centrifuge, colloids, crystallization, filtration, (isomerism), (inversion), solubility, hydrolysis, and evaporation.

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## UNIT ON RUBBER

Rubber can be termed one of the largest industries in this country. It is used in many places such as tires for automobiles, bicycles, etc. It is used to make rubbers and overshoes, elastic bands, insulators, erasers, etc. The following table may help to show the size of our trade in rubber, the figures being taken from page 299 of the World Almanac.

<u>Year</u>	<u>World Production</u>	<u>U.S. Imports</u>	<u>U.S. Consumption</u>
1928	657,305 Tons	439,727 Tons	430,000 Tons
1929	857,434 "	561,454 "	469,000 "
1930	821,815 "	488,343 "	372,627 "

From these figures one can see that this country has been importing better than half the rubber produced in the world.

India rubber or Caoutchouc is suspended in minute globules in the juice of certain plants. Most of the rubber comes from trees in South America, Africa, and the East Indies. Formerly the trees were wild; but since 1900 plantations of these trees have been set out, and now they furnish the largest and purest part of the world production, yielding 800,808 long tons in 1930. The trees are tapped and the white latex collected. The rubber is coagulated by exposing to wood smoke or by adding acetic acid, formalin, salt solution, etc., to the latex. It is then shipped to the fabricating plants.

This crude rubber is not ready for consumption, as it contains much dirt and its properties are not satisfactory

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Year	World Production	U.S. Imports	U.S. Consumption
1928	857,308 Tons	432,727 Tons	430,000 Tons
1929	857,434 "	521,424 "	482,000 "
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This crude rubber is not ready for consumption as it contains much dirt and its properties are not satisfactory

for common usage. It is very elastic, but has a very slow recovery. It is very adhesive, so that two surfaces of rubber will cling together strongly. It is also very susceptible to temperature changes, being soft and sticky when warm, and very brittle when cold. The problem for chemistry is to so treat rubber that it will retain its good points and reduce its bad points. As usual the answer was very simple and discovered by accident, but on it our whole rubber industry hinges. The importance of this treatment can easily be shown by comparing raw and finished rubber.

Rubber is fairly new in the world. Columbus found the Indians playing with balls of crude rubber. Pizarro found the Incas smearing it over their coats to make them waterproof. The trees grow wild in Anam so there was no need to wait for the discovery of America. However, its uses were not soon found out. Magellan in 1772 recommended its use to remove pencil marks. In 1825 Mackintosh made his name famous by putting a layer of rubber between two layers of cloth. Finally in 1839 Goodyear discovered the secret of vulcanizing and that is the basis of our modern industry.

A friend of Goodyear had a dream that sulphur would harden rubber and for ten years Goodyear tried but not until he dropped, by accident, some sulphur and rubber together on a hot stove was the secret of the necessity of heat plus sulphur revealed. This enabled him to make rubbers that would wear. By varying the amount of sulphur he found he could vary

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its hardness so as to make substances such as "hard rubber". In 1846 Thomson made the first pneumatic tire. In 1888 Dunlop tied some of these around his son's velocipede and the modern tire industry was started.

In the preparation of the finished rubber, the crude rubber is first cleaned mechanically by washing with water. This is done by grinding it while hot and playing the water over it. Then it is dried and sent to the mills. Here it is run between rollers which are steam heated to make it plastic. Fillers are added here. They consist of vulcanizing material (sulphur or some metallic sulphide), catalytic agent to aid vulcanization, coloring material, weighting material, and rubber substitutes. When thoroughly mixed it is ready to be moulded into whatever form desired, and then vulcanized by placing in steam heated chambers.

Rubber owes its property of being vulcanized to the fact that it contains two  $C=C$  groups that are capable of adding some element or chemical group at these points in the molecule. This same group is met with in other industries we deal with. Chemists have known for some seventy years how to take rubber apart but not how to put it together. They knew that  $(C_{10}H_{16})=2$  Isoprene  $(C_5H_8)$ . Tilden in 1892 had a bottle of isoprene reverse to rubber but could not repeat it. Again the first success was by accident. Dr. Mathews in 1910 set some isoprene over sodium to dry in a bottle and left it. When next

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isoprene over sodium to dry in a bottle and left it. When next

he looked at it two months later, he had rubber. The big problem now confronting the rubber industry is to find a cheap source of isoprene so it may be turned to rubber economically. This country and many others are dependent on the tropics for their rubber, and must pay what the grower asks. If synthetic rubber can be made economically, this country will not be dependent on others totally for its supply.

In brief then what should be undertaken in a unit on rubber are:

I. Importance to the Country.

- References a) Slosson "Creative Chemistry" Revised  
b) World Almanac (for actual consumption)

II. Present Source of Rubber.

- References a) Slosson "Creative Chemistry" Revised  
b) Thorpe "Outlines of Industrial Chemistry"  
c) The India Rubber World

III. Why Rubber must be Treated.

- References a) Thorpe "Outlines of Industrial Chemistry"

IV. History of the Treatment and Usage of Rubber.

- References a) Slosson "Creative Chemistry" Revised  
b) Bradfory "Historical Sketch of Chemistry of Rubbers".  
Science Progress Vol. II pp. 1.

- c) Iles "Leading American Inventors"  
(Chapter on Goodyear)

V. Brief Description of Treatment and Why it is Treated that Way.

- References a) Thorpe "Outlines of Industrial Chemistry"  
b) Moore "Outlines of Organic Chemistry"

VI. The Problem of synthetic rubber.

- References a) Slosson "Creative Chemistry"  
b) King "Synthetic Rubber" Metallurgical and Chemical Engineering, May 1, 1917.  
c) Tilden W. "Chemical Discovery and Invention in the Twentieth Century".

he looked at it two months later, he had rubber. The big problem  
now confronting the rubber industry is to find a cheap source of

Latex as it may be turned to rubber economically. This  
country and many others are dependent on the tropics for their  
rubber, and must pay what the grower asks. If synthetic rubber  
can be made economically, this country will not be dependent on  
others totally for its supply.

In brief then what should be undertaken in a unit  
on rubber are:

- I. Importance to the country.  
References a) Sisson "Creative Chemistry" Revised  
b) World Almanac (for total consumption)
- II. Present Source of Rubber.  
References a) Sisson "Creative Chemistry" Revised  
b) "Outline of Industrial Chemistry"  
c) The India Rubber World
- III. Why Rubber must be treated.  
References a) "Outline of Industrial Chemistry"
- IV. History of the Treatment and Use of Rubber.  
References a) Sisson "Creative Chemistry" Revised  
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Rubbers"  
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References a) "Outline of Industrial Chemistry"  
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- VI. The history of synthetic rubber.  
References a) Sisson "Creative Chemistry"  
b) King "Synthetic Rubber" Metallurgical and  
Chemical Engineering, May 1, 1914.  
c) Dixon W. "Synthetic Rubber and Invention  
in the Twentieth Century".

VII. (Recovered Rubber)

Reference a) Thorpe "Outlines of Industrial Chemistry".

To run an experiment showing the details of the production of finished rubber will require some care. The crude rubber (a pound or two) could be acquired from some plant in the vicinity. It might perhaps be washed by heating in warm water and running through a ringer and spraying warm water on it to wash it. After drying, its properties should be compared carefully with finished rubber. The milling could be done with the wringer again. The heating would have to be carefully attended to by heating the free roller with bunsen burners. Care must be taken that the flames would not touch the rubber. If there were one or two students sufficiently interested, a working model of the mills might be made. The fillers could be sprinkled on while the rubber is milling. The vulcanizing could be done by placing in a covered beaker and heating to the proper temperature. The milling might be done in three batches with varying amounts of sulphur to show various degrees of hardness can be obtained.

Another experiment might be carried out with isoprene. Some of this might be acquired and placed over sodium and transformed to rubber.

Materials required would be as follows:

- |                                  |                                      |
|----------------------------------|--------------------------------------|
| 1. A wringer or model of mill.   | 1. One or two pounds of crude rubber |
| 2. 3 or 4 one liter beakers      | 2. Hot Water                         |
| 3. Bunsen burners                | 3. Sulphur                           |
| 4. Glass Tubing and rubber hose. | 4. Weighing & Coloring materials     |
|                                  | 5. Isoprene                          |
|                                  | 6. Sodium                            |

To run an experiment showing the details of the production of finished rubber will require some care. The crude rubber (a pound or two) could be acquired from some plant in the vicinity. It might perhaps be washed by heating in warm water and running through a ringer and spraying warm water on it to wash it. After drying, its properties should be compared carefully with finished rubber. The milling could be done with the wringer again. The heating would have to be carefully attended to by heating the free roller with burner burners. Care must be taken that the flames would not touch the rubber. If there were one or two students sufficiently interested, a working model of the mills might be made. The rollers could be sprinkled on while the rubber is milling. The vulcanizing could be done by placing in a covered beaker and heating to the proper temperature. The milling might be done in three batches with varying amounts of sulphur to show various degrees of hardness can be obtained.

Another experiment might be carried out with isoprene. Some of this might be acquired and placed over sodium and transformed to rubber.

Materials required would be as follows:

- 1. A wringer or model of mill.
- 2. 3 or 4 one liter beakers
- 3. Burner burners
- 4. Glass tubing and rubber hose.
- 5. Isoprene
- 6. Sodium
- 1. One or two pounds of crude rubber
- 2. Hot Water
- 3. Sulphur
- 4. Weighing & Coloring materials

The following things should be mentioned to facilitate an understanding of the processes in back of the industry; colloids, mixtures as opposed to compounds, polymerization, and unsaturated linkages.

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## UNIT ON FERMENTATION INDUSTRIES

There are various products that are obtained in the fermentation industries. Among those that are prepared commercially in this country are alcohol and alcoholic drinks, carbon dioxide, lactic acid, vinegar, and yeast. It has also been possible to prepare other substances such as acetone (a solvent), butyl and amyl alcohol. Amyl alcohol is used as a basis for perfumes. Thus we see there are various types of products prepared in this industry and since beer has returned there will probable be a great increase in the industry. The products are used in various fields. Alcohol and acetone are used extensively as solvents in industrial chemistry. Carbon dioxide is used to charge our soft drinks. Lactic acid is used as a mordant in dyeing, and in treating skins to make leather. Yeast is used in cooking, and vinegar has household uses. Butyl alcohol and butyl acetate have sprung into use recently as solvents for lacquers. The following figures represent the amounts used and produced of some of these products.

<u>Year</u>	<u>Industrial Alcohol</u>	<u>Carbon Dioxide</u>		<u>Vinegar</u>	<u>Yeast</u>
1929	\$54,284,665	136,930,311 lbs.		\$10,450,332	
1927	33,971,150	74,344,287 "		10,755,246	288,195,440 lbs.
1925	* 31,854,085	59,721,309 "		12,233,099	

\* This figure is for 1919.

These figures are taken from the 15th census of the U. S. Vol. 2 Manufactures. The actual figures of volume production of alcohol and vinegar could not be found so the value of the product is used instead.

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Year	Industrial Alcohol	Carbon Dioxide	Vinegar	Yeast
1927	\$24,284,888	136,930,211 lbs.	\$10,450,232	388,192,440 lbs.
1926	22,971,180	14,244,287 "	10,752,346	
1925	* 21,864,082	22,721,309 "	12,322,092	

\* This figure is for 1919.

These figures are taken from the 18th census of

the U. S. Vol. 2 Manufactures. The actual figures of volume

production of alcohol and vinegar could not be found so the

value of the product is used instead.

The fermentation industries have had a peculiar history. They have developed along with the alcoholic drinks, and with a very peculiar branch of chemistry --crystals. The connection will be shown later. It has been known for a long time that certain fruit juices, etc., will ferment to give an intoxicating liquor. Noah in the bible is mentioned as having made wine. For a long time wine was the strongest thing that man could make. The Arabs found that wines could be distilled to yield brandies and whiskeys that were much stronger. However, this unit is not to be one on strong drinks.

It was not understood just what happened in the fermentation of sugars and starch. Man only knew that he must have yeast present. But sometimes the reaction would not go the way it should. For instance, if beer were the product, it might sometimes become very sour due to lactic acid being formed. Now this whole industry was explained in a peculiar fashion. Pasteur had been working on the subject of crystals. In particular he was studying tartaric acid (obtained from the fermentation of wine). Now there doesn't seem to be anything peculiar about the crystals of tartaric acid, but Pasteur had two samples. One of these samples if it had polarized light passed thru it would turn the plane of polarized light to the right while the other would not turn the plane at all. On careful examination Pasteur found that the second consisted of equal amounts of his first sample and another kind of tartaric acid that turned the plane of polarized light to the left, and by the aid of the

The fermentation industries have had a peculiar history. They have developed along with the alcoholic drinks, and with a very peculiar branch of chemistry--crystals. The connection will be shown later. It has been known for a long time that certain fruit juices, etc., will ferment to give an interesting liquor. Now in the bible is mentioned as having made wine. For a long time wine was the strongest thing that man could make. The Arabs found that wines could be distilled to yield brandies and whiskeys that were much stronger. However, this unit is not to be one on strong drinks.

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microscope he was able to separate them mechanically. This occurred in 1848.

Now it is tiresome work to separate crystals in that manner, so he was trying to find some manner of separating and obtaining the pure laevo-tartaric acid. He obtained a sample from Strassburg that to his astonishment was laevo-rotatory. This was the first sample of this known. On investigation it was found that a certain mould attacked the dextro rotatory and left the laevo-rotatory alone. This led Pasteur into investigating the action of various ferments. About this time the beer industry in France was in trouble. They were not obtaining good beer, but a sour beer. Pasteur was called in and on his investigations found that the trouble was with their ferment or yeast. They had impurities in it that were forming lactic acid. Pasteur found that there was one ferment that would form one type of beer, another, another type, and a third might make a certain type of wine.

In 1680 Leeuwenhoek had examined yeast under the microscope and saw it was a mass of small cells. In 1838 Cagniard-Latour had shown that it was a living organism. In 1781 Lavoisier had correctly analysed alcohol and in 1828 Hennell had synthesized it. In 1831 Coffey had devised a very efficient still to obtain alcohol. The growth of the aniline dye industry caused a great demand for cheap alcohol. In 1870 it was found that molasses could be used to make this industrial alcohol, but was not satisfactory for whiskeys. Between 1870 and '80, E. C. Hansen in

microscope he was able to separate them mechanically. This occurred in 1848.

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Copenhagen carried on extensive work on yeasts and was able to separate single cells, and by using suitable liquors and sterilized conditions he was able to obtain considerable quantities of pure cultures.

In 1837 Kützing had recognized that the fermentation of wine or alcohol to form vinegar was due to a living organism, and in 1878 Hansen isolated this. In 1892 Calmette isolated a mould that was capable of transforming starch to sugar and then to alcohol. In 1886 in "air yeast" process for making yeast for bakers was started commercially in England. A flaskful of desired inoculum for industrial purposes under proper conditions can in a week produce approximately 100 tons of yeast cells, that can be filtered, pressed into cakes, and delivered to bakers. In 1910 the French Chemist Fernbach discovered a ferment that could produce acetone and butyl alcohol, but unfortunately more butyl alcohol is produced; and as there is but little demand as yet for it, it is not economically practicable to use it. In 1921 Hutchinson and Richards discovered a ferment that would act on semi-liquified cellulosic material (e. g. straw) so as to make a valuable manure. It has also been found that if yeast is properly treated, that in ordinary fermentation for alcohol, large quantities of glycerine can also be obtained, and may in some cases be the source of glycerine from the soap works.

Thus the problem for the chemist in the fermentation industry is the selection of the right enzyme for the

Copenhagen carried on extensive work on yeasts and was able to separate single cells, and by using suitable liquids and sterilized conditions he was able to obtain considerable quantities of pure cultures.

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ferment that would act on semi-identified cellulosic material (e. g. straw) so as to make a valuable manure. It has also been found that if yeast is properly treated, that in ordinary fermentation for alcohol, large quantities of glycerine can also be obtained, and may in some cut into the source of glycerine from the soap works.

Thus the problem for the chemist in the fermentation industry is the selection of the right enzyme for the

product desired and the control of conditions so that the maximum yield is obtained in a minimum time.

We shall describe here the commercial process for the preparation of alcohol. The raw product is often corn. This is usually degerminated and ground to a coarse meal. It is placed in a digester with a stirring apparatus. Water is added and heated with steam under 2 or 3 atmospheres pressure for an hour or so. Then it is allowed to cool to  $63^{\circ}\text{C}$ , and ground malt is added. The  $63^{\circ}\text{C}$  allows a minimum of dextrin to be formed. The resulting liquid is sieved and rapidly cooled and sent to the fermenting vats. The rapid cooling prevents the forming of the acetic fermentation. The temperature here is about  $20\text{-}25^{\circ}\text{C}$  to prevent loss of alcohol by evaporation. To prevent the formation of wild yeasts a little alkali fluoride is added. When the fermentation ceases, we have a mixture of solids, water, 10-13% alcohol, fusel oil, acid, etc. The alcohol is now separated by fractional distillation. It is run thru for the first time for a rapid distillation to leave solids etc. behind. Next it is filtered thru a wood-charcoal filter that adsorbs a great deal of the fusel oil. Then it is given a careful fractional distillation and the following four fractions obtained.

1. Some alcohol, aldehydes, and ethers.
2. Alcohol (Cologne spirits) 95-6% alcohol.
3. Commercial alcohol. 80-95% alcohol.
4. Fusel oil.

When either 2 or 3 is sold for industrial purposes,

product distilled and the control of composition as that the

maximum yield is obtained in a minimum time.

We shall describe here the commercial process for

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This is usually degerminated and ground to a coarse meal. It

is placed in a digester with a stirring apparatus. Water is

added and heated with steam under 2 or 3 atmospheres

pressure for an hour or so. Then it is allowed to cool to 50°C.

and ground meal is added. The 50°C allows a minimum of bacteria

to be formed. The resulting liquid is allowed to rapidly cool and

sent to the fermenting vats. The rapid cooling prevents the

fermenting of the acetic fermentation. The temperature here is

about 30-35°C to prevent loss of alcohol by evaporation. To

prevent the formation of wild yeasts a little alcohol is added

is added. When the fermentation ceases, we have a mixture of

solids, water, 10-15% alcohol, sugar, etc. The alco-

hol is now separated by fractional distillation. It is run thru

for the first time for a rapid distillation to leave solids etc.

Behind. Next it is filtered thru a wood-charcoal filter that

removes a great deal of the yeast oil. Then it is given a care-

ful fractional distillation and the following four fractions

obtained.

1. Some alcohol, aldehydes, and esters.
2. Alcohol (colored spirits) 85-95% alcohol.
3. Commercial alcohol, 90-95% alcohol.
4. Fuel oil.

then either 2 or 3 is sold for industrial purposes.

to avoid high taxes, it is denatured with methyl alcohol and pyridine bases from bone-oil, or some other substances, and can be sold tax free.

Vinegar, lactic acid, etc., can be prepared from the same crudes or from dilute alcohol by treating with the appropriate enzyme.

Thus, in a unit on the fermentation industry one should consider the following points:

I. Various products of the fermentation industry and uses.

- Ref. a) Miall "History of the British Chemical Industry"  
b) Thorpe "Outlines of Industrial Chemistry"  
c) Plimmer "Chemical Changes and Products Resulting from Fermentation"  
d) 15th Census of the U.S. Vol. 2 Manufactures.

II. History of the development of the Industry.

- Ref. a) DeKrief "Microbe Hunters" (Chapter on Pasteur)  
b) Miall "History of British Chemical Industry"

III. The problem of the control of enzymes.

- Ref. a) Bayliss "The Nature of Enzyme Action"  
b) Plimmer "Chemical Changes and Products Resulting from Fermentation"  
c) Oppenheimer "Ferments and Their Actions"

IV. Description of Commercial Production.

- Ref. a) Harden "Alcoholic Fermentation"  
b) Thorpe "Outlines of Industrial Chemistry"

In the laboratory commercial alcohol could be prepared. Corn starch and malt can be mixed with water in a 5 liter flask at 63°C. and cooled to 20°C. Yeast can be added and allowed to ferment for 3 days at this temperature. The top of the flask could be hitched to an ejector and the gases given off during fermentation drawn thru lime water to show the generation of CO<sub>2</sub> by the formation of the white precipitate.

to avoid high taxes, it is denatured with methyl alcohol and pyridine bases from bone-oil, or some other substances, and can be sold tax free.

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the same grades or from dilute alcohol by treating with the appropriate enzymes.

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- I. Various products of the fermentation industry and uses.  
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c) Pinner "Chemical Changes and Products Resulting from Fermentation"  
d) 13th Census of the U.S., Vol. 2, Manufactures.

- II. History of the development of the industry.  
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- III. The problem of the control of enzymes.  
Ref. a) Baylis "The Nature of Enzyme Action"  
b) Pinner "Chemical Changes and Products Resulting from Fermentation"  
c) Oppenheimer "Ferments and Their Actions"

- IV. Description of Commercial Production.  
Ref. a) Harter "Alcoholic Fermentation"  
b) Thorpe "Outlines of Industrial Chemistry"

In the laboratory commercial alcohol could be

prepared. Corn starch and malt can be mixed with water in a 5 liter flask at 63°C. and cooled to 30°C. Yeast can be added and allowed to ferment for 3 days at this temperature. The top of the flask could be fitted to an ejector and the gases given off during fermentation drawn from lime water to show the generation of CO<sub>2</sub> by the formation of the white precipitate.

The vacuum should be just great enough so that a gentle stream passes thru the line water. A trace of NaF should be added. On finishing, the flask can be attached to a straight condenser and the mixture in the flask distilled. Then this filtrate should be slowly filtered thru a wood-charcoal filter to remove the fusel oil. Then it should be subjected to a very careful fractional distillation for the four fractions already mentioned. Then the strength of the fractions 2 & 3 can be determined by means of the specific gravity. Lastly, if absolute (200 proof) alcohol is desired it should be very slowly distilled over lime, metallic sodium, or calcium, and will yield alcohol very nearly dry. The fractions 2 & 3 not run to absolute alcohol should be denatured with 2% methyl alcohol as done industrially to avoid a higher tax.

Lactic acid can be prepared by fermenting sugar with *Bacterium acidilactici* over calcium carbonate. The resulting calcium lactate solution is concentrated and the acid formed by treating with sulphuric acid.

Vinegar can be prepared in the laboratory by fermenting the dilute alcohol solution with the acetic ferment. The alcohol solution should only be 2% or 3% and care should be taken to stop the reaction when all the alcohol is used as otherwise it may attack the acetic acid formed.

The materials needed would be as follows:

- |                            |  |
|----------------------------|--|
| 1. 5 liter flask           | 1. Corn Starch   |
| 2. Straight Condenser      | 2. Malt  |
| 3. Fractionating Column    | 3. Various ferments  |
| 4. Ejector                 | 4. Sodium Fluoride (NaF)   |
| 5. Glass and Rubber tubing | 5. $\text{Na}_2\text{CO}_3$ , CaO, $\text{CH}_3\text{OH}$ , and pyridine |
| 6. Bunsen Burner           | 6. Metallic Na or Ca   |
|                            | 7. Sulphuric acid.   |

The vacuum should be just great enough so that a gentle stream passes thru the line water. A trace of NaF should be added. On finishing, the flask can be attached to a straight condenser and the mixture in the flask distilled. Then this filtrate should be slowly filtered thru a wood-charcoal filter to remove the fusel oil. Then it should be subjected to a very careful fractional distillation for the four fractions already mentioned. Then the strength of the fractions 2 & 3 can be determined by means of the specific gravity. Lastly, if absolute (200 proof) alcohol is desired it should be very slowly distilled over lime, metallic sodium, or calcium, and will yield alcohol very nearly dry. The fractions 2 & 3 not run to absolute alcohol should be generated with 95 methyl alcohol as done industrially to avoid a higher tax.

Lactic acid can be prepared by fermenting sugar with *Bacterium acid lactici* over calcium carbonate. The resulting calcium lactate solution is concentrated and the acid formed by treating with sulphuric acid.

Vinegar can be prepared in the laboratory by fermenting the dilute alcohol solution with the acetic ferment. The alcohol solution should only be 25 or 30 and care should be taken to stop the reaction when all the alcohol is used as otherwise it may attack the acetic acid formed.

The materials needed would be as follows:

- |                            |                                     |
|----------------------------|-------------------------------------|
| 1. 5 liter flask           | 1. 500g Starch                      |
| 2. Straight Condenser      | 2. Milk                             |
| 3. Fractionating Column    | 3. Various Ferments                 |
| 4. Reflector               | 4. Sodium Fluoride (NaF)            |
| 5. Glass and Rubber tubing | 5. Na2CO3, CaO, CaSO4, and pyridine |
| 6. Bunsen burner           | 6. Metallic Na or Ca                |
|                            | 7. Sulphuric acid.                  |

SUMMARY OF THEORIES AND CHEMICALS USED.

The following theoretical points should be considered: enzymes and their action, distillation when there is a mixture with a constant boiling point lower than either constituent, and the preparation of acids from their salts by means of H<sub>2</sub>SO<sub>4</sub>.

Theory:

	Water	Iron	Nitrogen	Nitrogenous	Carbon-Oxygen Gas	Water Gas	Sulphur	Plastics	Paper	Cotton	Wool	Synon	Spinning	Glass	Soap	Sugar	Rubber	Fermentation	Acid	Caustic
1. Acids (Preparations, etc.)			4	5			7		10		11	12					17		19	
2. Absorption				5	6								13			18				
3. Bases (Preparations, etc.)							7		9	10	11	12	13		16		17			20
4. Bleaching									9	10	11	12								
5. Capillary Attraction									9			12								
6. Catalysis (Enzymes, etc.)			3										15					18	19	
7. Centrifuge				5			7		9	10	11	12	15			16				
8. Dyeing		1										12				16	17			
9. Dyeing				4	5											16		18		
10. Diffusion				4	5	6	7	8								16		18		
11. Crystallization	1	2					7							14		16				20
12. Dyeing									9	10	11	12	13	14						
13. Electrolysis (Leads theory, etc.)	1			5					9	10	11	12	13	14	16					20
14. Filtration		1										12				16		18		
15. Flammability & Combustion (Kindling point)				4	5	6														
16. Law of Definite Proportions etc.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
17. Molecular contraction (Laws)							7							14		16		18		
18. Oxidation-Reduction			3											14				18	19	
19. Polymerization							7					12					17			
20. Reactions (Acids, Alkalis, etc.)	1	2	3	4	5	6	7	8	9	10	11	12		14	15	16	17	18	19	20

The following theoretical points should be con- sidered: enzymes and their action, distillation when there is a mixture with a constant boiling point lower than either consti- tuent, and the preparation of acids from their salts by means of H<sub>2</sub>SO<sub>4</sub>.

CHAPTER V

SUMMARY OF THEORIES AND CHEMICALS USED.

It would be of interest to see what theories have been met with in the preceding units and see which ones are met with more times than the others. It also gives some clue as to what theories should be stressed and which only mentioned. The following table has been prepared to show this in detail.

Theory:

	Water	Iron	Nitrogen	Petroleum	Coke-Oven Gas	Water Gas	Tar	Plastics	Paper	Cotton	Wool	Rayon	Dyeing	Glass	Soap	Sugar	Rubber	Fermentation	Acid	Caustic
1. Acids (Properties, etc.)				4	5			7		10	11	12					17		19	
2. Adsorption				5	6								13			16				
3. Bases (Properties, etc.)								7	9	10	11	12	13		15		17			20
4. Bleaching									9	10	11	12								
5. Capillary Attraction									9			12								
6. Catalysis (Enzymes, etc)				3									13					18	19	
7. Centrifuge					5		7		10		11	12	13			16				
8. Colloids		1										12				16	17			
9. Cracking				4	6															
10 Distillation				4	5	6	7	8								16		18		
11 Crystalization	1	2					7							14		16				20
12 Dyeing									9	10	11	12	13	14						
13 Electrolysis (Ionic Theory, etc)		1			5				9	10	11	12	13	14	15				19	20
14 Filtration		1										12				16		18		
15 Flames & Combustion (Kindling point)				4	5	6														
16 Law of Definite proportions etc.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
17 Molecular construction (Isomers)							7							14		16		18		
18 Oxidation-Reduction			2	3		6								14				18	19	
19 Polymerization							7					12					17			
20 Reactions (conditions, etc.)	1	2	3	4	5	6	7	8	10		11	12		14	15	16	17	18	19	20



	Water	Iron	Nitrogen	Petroleum	Coke-Oven Gas	Water Gas	Tar	Plastics	Paper	Cotton	Wool	Rayon	Dyeing	Glass	Soap	Sugar	Rubber	Fermentation	Acid	Caustic
21 Replacement (Electrochemical series etc.)	1	2			5	7			9	10	11	12			15		17		19	20
22 Sanitation	1														15					
23 Saponification-Hydrolysis								9	10			12			15	16				
24 Solubility	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
25 Softening Water	1								9						15					
26 Specific heat and expansion	1													14						
27 Unsaturated linkages									10							16	17			

Then another point that should be considered is the chemicals that are used and the frequency with which they are used. The table on the following page shows the number of industries in which the chemical occurs.



Compounds	No. of Times Occurring
*Water	16
Sulphuric Acid	9
Caustic Soda	8
*Soda Ash	7
Oxygen	7
*Carbon	6
*Soap	5
*Sulphur	5
*Calcium Carbonate	4
*Calcium Sulphate	4
Carbon Dioxide	4
*Cellulose	4
Chlorine	4
*Iron	4
Glaubers Salt	4
Calcium Acid Carbonate	3
Magnesium " "	3
Calcium Chloride	3
Hydrogen Sulphide	3
*Sulphur dioxide	3
*Sodium Chloride	3
Sodium Sulphate	3
Benzene	3
Phenol	3
Carbon Monoxide	3
*Naphthalene	3
*Ferric Oxide	3

This gives us a list of chemicals that is fairly small. The properties as they occur in the industries are the properties that should be mentioned unless the pupils directly ask about other properties. Those that are starred are those about which the pupil should already have some knowledge.

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## METHODS OF TEACHING

The main method used in teaching the course should be one of appreciation. Our whole course is based on one main aim which is to give the pupils an appreciation of the role of chemistry in everyday life thru its applications in industry. Thus in the class room there is no demand for drill of any sort. The pupils should only learn the things brought to their attention by association. They should not be held responsible on a drill basis for various theories and properties of substances. There are certain fundamental theories that should be emphasized and called to the attention of the pupil whenever they occur. Perhaps the most important of these are the laws of definite composition and combining weights. These are the basis by which all reactions and tests are made. For instance we know that water is always  $H_2O$ . Then we know that 4.032 grams of hydrogen and 32.00 grams of oxygen always combine to give 36.032 grams of water. Thus in industry we can tell how much of one substance must be added to another substance so that in the resulting reaction there will be no excess of either. This law should not be drilled by countless problems, but problems should be done when met with in the industries with no attempt to state the law until several examples of it have been observed. There are one or two other laws that should be treated in this manner.

With regard to learning the properties of chemicals there is no demand that the complete properties of the chemicals be studied, but only those properties that are important for their industrial usage. Thus the chief properties of sulphuric

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With regards to learning the properties of chemicals there is no demand that the complete properties of the chemicals be studied, but only those properties that are important for their industrial usage. Thus the chief properties of sulphuric

acid would be as a drying agent, to neutralize alkalies, and its corrosive action on metals. These various properties should be mentioned as they occur in the units. As Brinkley (26) states, "The presentation of the properties of one element and its compounds after another, and the drill on equation writing and problem solving, necessary and desirable though these may be for the student who plans to major in Chemistry, have no place in such a cultural course".

Chemistry is an experimental science as very little has been learned except thru experiment. The average child knows very little about it when he first begins to study. It is then the teacher's task to see that the pupil gets the necessary knowledge of phenomena by actually seeing them either by experiment by the pupil or demonstration by the Teacher. Twiss claims that if pupils have facts, etc., told them, it tends to produce the habit in pupils of depending on the book for facts that they should find through their own experiences. Then on page 354 he states, "To create such an attitude at the start is fatal to the scientific spirit which it is the mission of science to teach. Furthermore, there is no meaning in a generalization or definition unless the pupils become acquainted thru first-hand experience with a considerable number of the specific facts of which the generalization or definition is a general or condensed statement.

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basis for the law or definition. Into whatever unit we start, we can bring some of our definitions such as the difference between physical and chemical changes. Demonstrations can be given along with the class-room work. These demonstrations can furnish the basis of the definition. As Twiss (15) page 356 says, "The teacher who knows how to work experiments for all they are worth, will bring out these differences clearly in connection with the experiments described; and if so brought out they will be better remembered because learned in connection with problems that can be seen to lead to some significant goal".

Thus every lesson can be said to contain problems. Even in our appreciative course the pupil can be made to feel a need by his observations. This need is to explain certain observed phenomena. He tries to cover these with a hypothesis and eventually gets the true one that covers the facts. The importance of this "hypothesis" is easily seen, as some industry important to the community uses this in their plant, and this has been the source of the phenomena for the creation of the hypothesis by the pupil.

The value of laws and hypothesis is that if they are understood thoroughly they become the basis for further thinking and for drawing valid conclusions. As Twiss again says on page 358, "But he cannot comprehend the laws and theories, and they cannot therefore be helpful to him, unless he first knows at least a considerable portion of the facts which the laws resume on the theories to explain". It is a reversible

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cycle. The facts give birth to the law, and the law predicts new facts.

The true function of the text book should be mainly that of a reference book for facts that cannot be easily obtained by direct experiment or observation in industry. It also is a valuable guide in logical organization and review of facts and principles. As Twiss says on page 357, "He (the teacher) will not send the pupil to the book beforehand to find out from the printed page what they should find out with their own eyes, noses, and hands. It is wrong to suppose that in the early stages of scientific study time can be saved by learning facts from books. The pupil does not learn the facts thus. He merely learns words and formulae which for him can have no content because he lacks the experimental knowledge which alone can enable him to appreciate them. Later on after he has accumulated a considerable amount of facts through first hand experience, has perceived their relations, and has formulated these relations, largely for himself, in the form of laws, principles and generalizations, he is in a position to use chemical books, articles and reports with the right attitude. The teacher, however, can never be too careful about hammering in the notion that everyone of the chemical facts that is to be learned from a book is simply a statement of results obtained by experiment, observation, and measurements, and by reasoning founded thereon."

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We should strive toward some theory, but as Twiss page 360 says, "Give them only so much of theory as will help

them better to interpret and organize the facts that they become acquainted with in the laboratory, at the demonstration table, and in the world outside, in the home, on the street, in the factory or on the farm". The applications of the theory should be of the most interest as it enables the pupil to understand their importance to him.

To further show this, trips should be made to the local industries on which the units are founded. This makes the industries real to the pupils. If they are not real, the whole point is lost, and he, the pupil, has only theories and facts that he must accept from the teacher. As Read (44) states the main objective is "To give students a better understanding and appreciation of the practical applications on a large scale of the laws and principles in the class room".

Thus visitation of local industrial plants becomes an essential part of the right teaching of an introductory course in chemistry. I am fairly certain that companies are willing to show their plants to an orderly group of pupils as it furthers the appreciation of their product. In several places I went this was specifically stated and in one place I was informed that in the next two weeks three such visits were to take place. My entire selection of units was based on industries that the pupils might have an opportunity to visit.

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From a consideration of the general principles set forth above, Twiss, pages 388-9, draws several "common sense"

rules that would be helpful to teaching our units. The important ones are as follows:

"Begin with the facts of observation and experiment and stick closely to such facts throughout the course".

"Withhold laws until a sufficient number of facts and relations that are specific cases of the law have been studied and have become familiar".

"When a law has been once presented have the pupils connect the statement of the law with every new specific case that comes under it until they habitually do this themselves".

"Withhold theories until they are needed to furnish explanations of observed facts".

"Laws and theories, therefore, should be introduced gradually as the course proceeds, and the more difficult conceptions should come near the end of the course".

"The laws of chemistry should always be expressed in such language as clearly to simply that they are statements of the results of experiment".

Another suggestion in teaching chemistry as put forth by Twiss is one that was used by Faraday in lecturing before children. Every time he mentioned gravity he dropped something. So whenever a teacher mentions something such as soda ash, pick up a bottle of it and exhibit it to the class. Another fact is that pupils should study the behavior of chemicals that are known to the pupils. As Twiss (15) pp.395 says, "Things totally unknown are not interesting. No interest,

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Inasmuch as chemistry is an experimental science, we may now turn with advantage to the laboratory side. There is a great controversy waging as to whether the experiment by the pupil is superior or inferior to the demonstration by the teacher. The results as set forth seem to indicate that the demonstration is superior for immediate recall but that the individual experiment may be best for delayed recall. There is considerable literature in the field, and reference will be made here to the article by Payne (41) that contains a summary of the articles on the subject up to the date of that article (1933). Two of the chief reasons put forth for the demonstration method are that it is time saving and money saving. The arguments put forth for the individual experiment are use in manipulating apparatus and the motivating principle behind it, as, to do something is satisfying.

Perhaps, until there is a final and definite answer, we had best quibble and say that a mixture of both is best. There have been some articles on the place of the demonstration experiment, and we can look at them. We find Gould (30) saying that demonstrations should supplement the individual experiment and be used to expand principles. The important thing is that they must illustrate a point.

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Rakostrew (42) has the following to say about the lecture demonstration, "Nothing is more tedious than to hear

a lecture that is a mere repetition of a chapter from a text". The demonstration should "give the mind something real to grasp".

Perhaps the best article is by Van Horne (55). He sets up five places for the demonstration experiment which are as follows:

1. Use at the beginning of the course as the pupils are too clumsy for anything but very simple experiments.
2. Use for dangerous experiments such as involve the use of chlorine.
3. Use for experiments that are difficult.
4. Use for experiments that are too long for the laboratory period.
5. Use to teach principles.

Then he sets up some precautions for the demonstrator that may well be noted.

1. Assign work in advance to avoid time pressure.
2. Check materials before very carefully.
3. Make sure the experiment will go even if it is necessary to go through it previously. Nothing can fall as flat as an experiment that does not work.
4. Make the experiment visible to all in the class.
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demonstration experiment should be carried out, it will pay us to turn the same attention to the individual laboratory work. The article by Henkel (33) is good. He has the "project" in mind for his laboratory work. He states, however, that the first half year should be spent on certain fundamental experiments to give the pupil a basis for the "projects". Then at the end of the first semester the pupil chooses a "project". Several that he mentions are a soil analysis, or the percentage of iodine in Lake Michigan. These "projects", or as we may call them laboratory units, might perhaps take on a more industrial aspect as in the case of those described by Williams (58) (59) (60) which will be mentioned later. There are four factors that must be taken into consideration --(1) time, for completing laboratory unit (2) books should be available so the student will know how to proceed (3) equipment so the pupil will have the material to work with (4) and the personal equation.

Then he has the following to say, "After the subjects have been chosen, the work moves on smoothly until the inevitable period of failure and discouragement sets in. The tiding over of this period requires much care, for failure in his chosen work is more disastrous to a pupil than is failure in a set task. ---- If he fails in which he himself has planned, he loses self respect and self confidence".

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There are two other articles by Southern (50) and Stone (53) which suggest laboratory units of a more practical nature. In the school Southern writes about, substances are prepared from their ores for an exposition at the end of the year. This must of necessity be practical as the methods used in industry are in many cases those used in the laboratory. It would be very easy to tie this work into industry by a trip through a plant making the compound from the crudes so the pupil can see the apparatus the plant uses. In the school Stone writes about, the compounds were actually used as reagents in the laboratory. Thus besides the practical production of the compounds we get the consumption of them and the way one industry depends on another. This is an important point to bring out.

Perhaps the best laboratory units for our industrial units are the three described by Williams (58) (59) (60). In each case a miniature plant for the production of some product was made and operated. The three products made were coke oven gas, nitrogenous fertilizer, and Karo syrup. The syrup was made and exhibited. The nitrates were used to fertilize a

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plant and this plant compared with an unfertilized one for growth. In the last a battery of two ovens was made and operated, tar collected, and finally the gas burned. All three of these were excellent and could be used in our course very well as they were actual working models of the industrial plants and incorporated all of their problems.

There is one other problem that comes up with regard to the laboratory or demonstration work. This is whether the material should be studied before or after the experiment. The evidence on this is again inconclusive. For instance, Bagley (22) finds that the knowledge of what the results of an experiment are before the experiment, has no appreciable effect as judged by standardized tests. She also finds that for pupil of low I.Q. they profit slightly on both immediate and delayed recall by the following sequence -- class discussion -- experiment -- and class work. For pupils of high I.Q. it made no difference whether the experiment or class work was completed first.

Parr (40) finds that the evidence seems to point to recitation first though the loss on delayed recall is greater. He also states that "A teacher's preference has an influence upon his success in teaching by experimental procedures". Thus until definite results have been obtained it seems best to leave this subject to the discretion of the individual teacher.

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be used in experimental work. For the individuals in the laboratory we can have as our main aim the laboratory unit of the type set forth by Williams. The type of work for these has been roughly sketched in our units. The pupils should be encouraged to devise and set up their own apparatus. For this reason it may perhaps be well to hold the laboratory work of this type until after the visit to the plant where they can see the actual commercial operations. The teacher should have a set plan at hand for apparatus so that he will be able to offer suggestions to pupils who get stuck in trying to devise apparatus. As these laboratory units will stretch over some period of time, it will be well to have only a few pupils working on any one unit. They can be paired or can work separately. Thus at one time, there may be people working on several units at the same time.

Then to take care of pupils who are unable to work on their unit during laboratory period, there should be other simple experiments to be performed. For example, the key reaction of an industry may be performed to give a clear idea to all. Another thing that can give a number of experiments for all is the study of some of the simple properties of the compounds studied. Thus the class as a whole can get a number of small experiments to fill out the laboratory time and give a clearer understanding of chemistry. The substances studied in the second group would be such as caustic soda, soda ash, etc. The properties looked for would be whether it had water

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of crystalization, solubility in water, color, etc.

Thus we may now set up a tentative plan for our course.

I. Large Industrial Units.

- a. Plant or household visits
- b. Class discussion of visit
- c. Demonstration to clinch any point or theory

II. Major Experimental Units.

- a. Project type of experiment to clinch unit to follow visit.
- b. Only part of class on any one unit

III. Minor Laboratory Units.

- a. To give idea of key reaction in industry
- b. To give idea of properties of chemicals met with in the units.
- c. Part of class not on II to work on this.

IV. Text and other literature depend on units.

- a. To be a reference
- b. For review.

As a start in laboratory work some attention should be paid to the manipulation of apparatus, use of the bunsen burner and ejector, and the heating and bending of glass and glass tubing. This is perhaps the only branch of the course where drill might be permissible, as the right handling of material will be important later in the work.

Then for the demonstration we can show experiments to help show definitions or laws as they occur. In order to save time and possible failure on the part of the pupil to obtain the right results, this is superior. This gives a way of obtaining additional information in a hurry when a law or definition occurs in class. The precautions should be followed as

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previously set forth.

The general plan as here proposed will be clarified by setting up one demonstration and showing how it might be carried out. In order to take a simple one that all pupils know something about, I shall take the question of the solubility of solids in liquids and the effect of temperature. There are three main types of solids here, those whose solubility increases with a rise in temperature, those in which it decreases, and those in which it remains fairly constant. Of course, there is a fourth type that are insoluble or very sparsely soluble. In the first class as an example we have sugar that is more soluble with a rise in temperature. In the second class we have calcium hydroxide or slaked lime that is less soluble with a rise in temperature. In the third class we have sodium chloride or salt that is about as soluble in hot as cool water. For our fourth class we have sand ( $\text{SiO}_2$ ) -- insoluble at all temperatures.

The first thing we should do is show the pupils our four types of solids and be sure they know them. Then we can set up four beakers with tap water in them. To the first beaker we can add sugar until no more dissolves, and then we can add sand to the second beaker. This is insoluble in water, and we can stir as long as we want but none dissolves. Next we can add salt to the third beaker until no more dissolves, and then we can add slaked lime in a similar manner to the fourth beaker. The resulting solutions are called saturated solution, and the definition of this word is our first point.

gravitationally well isolated.

The general idea of a more compact will be explained

by setting up the Hamiltonian and showing how it might be  
expanded out. In order to take a single one last all parts know

something about, I shall take the question of the stability  
of orbits in the field and the effect of temperature. There are  
three main types of orbits here, those which are actually unstable

with a rise in temperature, those in which it decreases, and  
those in which it remains fairly constant. Of course, there is  
a fourth type that are unstable or very nearly stable. In

the first class as an example we have a particle in a core orbit  
with a rise in temperature. In the second class we have a particle

in a core orbit which is stable but as the temperature rises it  
becomes unstable. In the third class we have a particle outside of the

core that is stable in a hot or cool water. For our purpose  
class we have found (1902) -- unstable at all temperatures.

The first thing we should do is to see the stability  
of our four types of orbits and to see they know what. Then we  
can set up the Hamiltonian with the water in the first

beaker we can add sugar until no more will dissolve, and then we  
can add salt to the second beaker. This is unstable in water,

and we can stir as long as we want and have dissolved. And  
we can add salt to the third beaker until no more dissolves, and

then we can stir it in a similar manner to the fourth  
beaker. The resulting solutions are called saturated solutions,

and the definition of this word is our first point.

All these solutions should be at one temperature. When we have put across the point of soluble and insoluble, and saturation, we can proceed to the next point which is the effect on solubility of an increase in temperature. All of the beakers can be raised 25° by applying a flame. There is still no effect on the beaker with sand in it. In the one with slaked lime, some of it will have settled out showing it is less soluble than before. The other two are the same. If a little salt is added to that beaker a slight increase in solubility may be noted, but only very slight. On the other hand the sugar solution will dissolve much more. Thus we find that an increase in temperature can either increase or decrease the solubility of a salt, or hardly alter the solubility.

Now most salts are more soluble with an increase in temperature, and this should be shown. Some of the pupils know the following compounds, nitre, boric acid or borax, bicarbonate of soda, and soap. All of these are more soluble in hot water. We now have shown that there are soluble and insoluble salts, the effect of temperature, and that most salts are more soluble in hot water. If time permits it might be well to use alcohol as a solvent and show that the same things are true there. It should also be shown that the solubility of a solid in one solvent is not necessarily the same in another solvent.

This work should proceed very slowly and should involve the help and cooperation of the pupils. The pupils

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might do all of the work, the teacher sitting by and directing. The teacher could help set the problem; the pupils should write the conclusions. It takes time to think, particularly in a new field. The wise teacher will not press. Let the pupils play along slowly enough to get the meaning.

There is one more point with regard to the laboratory work. The experiments at the end of each unit have not, unfortunately, been tried out in the laboratory. Therefore, there are some that may or may not work, or are extremely dangerous to try. This part of the units needs further study. Some of the experiments, such as those for the Birkeland-Eyde process and the Coke-Oven Gas have been tried and found to work successfully. Others, such as on soap and dyeing, are similar to experiments found in laboratory manuals and are known to work successfully. These types are all right for laboratory experiments. Those units on which the laboratory work was starred are those that the laboratory work is purely theoretical and there is no saying it will work, or, if it works, whether the product is sufficiently good to be shown as the result of the process. These starred experiments should be tried out very carefully by the teacher before being used to see if they will work satisfactorily.

Another point to consider is whether the laboratory is equipped to carry out the experiment with safety. Thus the experiment on Water Gas should not be run unless there are hoods in the laboratory and they are in good running condition.

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Another point on being careful is to have a good margin of safety with experiments involving high pressure. This is to prevent explosions resulting in injury and damage. Thus, if the laboratory is equipped properly, and proper precautions taken, these experiments may be tried if they have been found to work properly. But, if the experiment does not work properly, or if it is too dangerous to run, it must be omitted and something else substituted.

The teacher should not try to shift too quickly to this type of work. One unit should be tried out first, and if this is satisfactory, another may be tried the same year. The next year the same two may be repeated and one or two new ones added so that the entire shift to this type of work will be gradual and allow the teacher full opportunity to grasp the full possibilities of this type of work. The teacher should start with the units which have satisfactory laboratory work. Then in preparation for those with purely theoretical laboratory work, the teacher may be trying the experiments to find if they are satisfactory, or may read of someone else who has successfully accomplished it.

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## CONCLUSIONS

- I. There is considerable doubt about the value of a course in chemistry as now taught.
- II. The present course is not meeting the main aim set forth for it of fostering the scientific attitude.
- III. The present course is doing little or nothing to teach appreciation of chemistry in every day life.
- IV. There is a great deal of feeling that the appreciation of chemistry in every day life should be the main aim.
  - a. Sub-aim: To foster the scientific attitude.
- V. A course of study can be set up that will very probably meet these aims. The course will be as follows:
  - A. Subject of Course.
    1. Units based on the uses of chemistry in Industry.
    2. Units based on household and everyday uses.
  - B. Limitation of Units.
    1. Must be available for pupil inspection.
    2. Must be simple enough for pupil comprehension.
    3. Must be of local importance.
  - C. Methods.
    1. Primarily appreciation.
    2. Eliminate drill.
    3. Derive laws and hypotheses after sufficient data is present on which to base them.
    4. Use individual laboratory experiments or procedure for clinching the industrial units and chemical properties.
    5. Use demonstration to give extra data for derivation of laws, hypotheses and definitions.
    6. Eliminate all work on chemicals of little or no importance to units studied.
    7. All learning other than laboratory technique should be incidental coming along with the study of the applications of chemistry.

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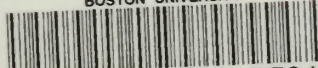
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